Faculty of Electrical Engineering, Mathematics and Computer Science

MSc Sustainable Energy Technology

A combined niche transition and energy justice study of biomass gasification in Indonesia

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Summary

Problem Statement

Indonesia is the world's largest archipelago nation, with 270 million people inhabiting 6,000 islands that span almost 2000 square kilometers (World Population Review, 2020). With 80% of its industries and 60% of its population located in coastal regions, Indonesia is particularly vulnerable to rising sea-levels and extreme weather events (Fünfgeld, 2020). Despite the urgent need to transition towards low carbon energy production, the development of renewables in Indonesia is very slow. In 2019, 84% of electricity was generated from fossil fuels, 59% of which came from coal power plants (IEA, 2020b). Considering the prevailing poverty levels, which stood at 24% in 2018 ($ 3.20/day poverty line), Indonesia is faced with the dual challenge of human development and climate change. Biomass gasification is a particularly interesting option for Indonesia due to the enormous quantities of residues produced from the agriculture and forestry sectors. Activities commenced in the late 1970's, however, despite over forty years of development the technology has not reached wide-scale diffusion and very few clear examples of commercially viable projects exist. Further investigation is needed to understand how biomass gasification can contribute to energy justice in Indonesia, and which factors have influenced its development over the past forty years.

Research Goals and Research Design

Theory from sustainability transitions research and energy justice are used to develop a framework that facilitates the investigation of: (1) the factors that have influenced the development of the biomass gasification niche, and (2) how niche projects and the electricity sector have performed with respect to energy justice. An integrated Multi-Level Perspective (MLP) and Strategic Niche Management (SNM) framework is combined with the energy justice framework of Sovacool, M. Burke, et al., 2017. Explanatory and descriptive research is complemented by exploratory research, that utilises semi-structured expert interviews to gain deeper insights into transition dynamics and energy justice.

Main Findings

The biomass gasification niche has largely relied on international donors to support activities. In 1980 the main landscape pressure motivating donors was energy (in)security during the world oil crises. Many years later, international and domestic interest in biomass gasification increased largely in response to the intensifying landscape pressure to mitigate climate change. Projects have been implemented in rural locations where there is a need to: alleviate poverty, increase electricity access, and reduce diesel fuel consumption. The latter is due to the increasing burden of oil subsidies and rapidly declining domestic oil reserves.

Since 2012 a number of formal rules have been introduced in order to incentivise biomass gasification projects - these started with fixed Feed-in-Tariffs, and later linked the electricity price to the local generation cost of the electricity utility, PLN. Both regulations failed to incentivise commercial projects, while the latter was widely regarded as inhibitory to niche development as PLN's generation cost is heavily influenced by fossil fuel subsidies (Interviewee 5 - International Project Facilitator, 2020; Interviewee 8 - Government, 2020). The increased use of biomass for cofiring with coal has led to the formation of a domestic market for waste biomass - these feedstocks have since been prohibitively expensive for niche projects.

As the niche network has expanded beyond technical research institutions, the learning processes progressed to learning about policy and regulation, biomass potential, societal and environmental impact, and business models. Knowledge of biomass potential has greatly improved - while the domestic market for biomass waste has made agribusiness waste prohibitively expensive, the Centre for International Forestry Research (CIFOR) has started to investigate the potential of different biomass species for cultivation on degraded land - creating a key opportunity for niche projects to align with the land-use dimension of climate change mitigation. Finally, in CPI's recent projects, actors have been able to learn more about the societal and environmental impact of biomass gasification - a key source of competitive advantage over other renewable energy niches (discussed below).

However, the success of niche projects to date have been hampered by a variety of socio-technical challenges, several of which still remain - feedstock security, operator training, and business models to facilitate niche expansion. In terms of the actor network, there has been minimal interaction between the different actor groups over the last forty years - this lack of shared learning has meant that actors have not been able to effectively learn from the accumulating experiences of other niche projects, and so resulted in limited examples of reinforcing niche nurturing processes and second-order learning.

Since the earliest niche experiments in 1980, biomass gasification projects have attempted to alleviate some of the injustices caused by Indonesia's electricity regime. By targeting rural communities that have been marginalised by poor access to energy services, projects have sought to alleviate the **intra-generational inequity** in the **availability** of electricity. Through careful project design, actors were able to contribute to improved **transparency and accountability** and alleviate some injustices that **intersect** with energy justice. Regarding the latter, the main contribution has been in the targeting of low-income rural communities with limited access to electricity (socio-economic justice), although CPI's Mentawai project also contributed to improved gender justice.

Recommendations

The key recommendations from this research are: (1) align projects with multiple landscape pressures - choose locations in which these pressures are more intense by comparing biomass potential (agro-industry locations or degraded land for crop cultivation), to the locations of diesel power plants (and regions in which the local generation cost is high), and locations of communities with poor electricity access and limited economic development; (2) accelerate niche development by improving cross-project communication; (3) implement long-term strategy to improve technical knowledge in rural areas so that communities are able to successfully operate and maintain biomass gasification plants, and (4) the Government should adopt an energy justice framework, such as that proposed by Sovacool, M. Burke, et al., 2017, that not only considers distributional justice, but also due process, recognition, restorative, and cosmopolitan justice - this will result in supportive policies that more accurately value the positive energy justice contribution of niche technologies like biomass gasification, and thereby facilitate the large-scale diffusion of these technologies.

Further work

This historical case study can be used as the basis for a participatory future-oriented research project that investigates how the biomass gasification niche can be *scaled-up* in a *just* manner - designing a number of scenarios over the short-, medium-, and long-term. Considering the broad scope of Indonesia's electricity sector, a more comprehensive energy justice analysis is necessary for niche innovations and traditional technologies in order to facilitate fair energy decision-making.

This research has *combined* an integrated MLP and SNM framework with an energy justice framework. Sovacool's broad energy justice framework creates a number of opportunities for integrating this analysis into the MLP and SNM frameworks. Academically relevant further research should focus on the *integration* of energy justice and Sustainability Transitions Research frameworks.

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Acronyms

ADB Asian Development Bank.

AMDAL Environmental Impact Management Analysis [Analisis Manajemen Dampak Lingkungan].

APEX Asian People's Exchange.

ASCENT Ankur Scientific Energy Technologies.

BAPPEDA Regional Development Planning Agency [Badan Perencana Pembangunan Daerah].

BAPPENAS National Development Planning Agency [Badan Perencanaan Pembangunan Nasional].

BGMP Biomass Gasification Monitoring Program.

BNI Bank Negara Indonesia.

BPP Cost of Production [Biaya Pokok Produksi].

BPPT Agency for The Assessment and Application of Technology [Badan Pengkajian Dan Penerapan Teknologi].

CDM Clean Development Mechanism.

CIFOR Center for International Forestry Research.

COPD Chronic Obstructive Pulmonary Disease.

CPI Clean Power Indonesia.

DEN National Energy Council.

DGE Directorate General of Electricity.

DGNREEC Directorate General of New and Renewable Energy and Energy Conservation.

DMO Domestic Market Obligation.

EJ Energy Justice.

GCF Green Climate Fund.

GIZ German Society for International Cooperation [Deutsche Gesellschaft für Internationale Zusammenarbeit].

GPE Gasifikasi Prima Energi.

HTI Industrial Tree Plantation [Hutan Tanaman Industri].

ICED Indonesia Clean Energy Development program.

IDR Indonesian Rupiah.

IEA International Energy Agency.

IIEE Indonesian Institute For Energy Economics Foundation.

IO Captive Power Producers.

IPP Independent Power Producer.

KPK Corruption Eradication Commission [Komisi Pemberantasan Korupsi].

KUBE General Energy Sector Policy [Kebijakan Umum Bidang Energi].

LMIC Low- and Middle-Income Countries.

LNG Liquefied Natural Gas.

LTSHE Energy Saving Solar Lights [Lampu Tenaga Surya Hemat Energi].

MCA-I Millennium Challenge Account – Indonesia.

MCC Millennium Challenge Corporation.

MEMR Ministry of Energy and Mineral Resources.

METI Indonesian Renewable Energy Society [Masyarakat Energi Terbarukan Indonesia].

MKI Indonesian Electrical Power Society [Masyarakat Ketenagalistrikan Indonesia].

MLP Multi-Level Perspective.

MoA Ministry of Agriculture.

MoEF Ministry of Environment and Forestry.

MoF Ministry of Finance.

MOU Memorandum of Understanding.

MSOE Ministry of State-Owned Enterprises.

MSW Municipal Solid Waste.

NDA National Designated Authorities.

NDC Nationally Determined Contribution.

NEP National Energy Policy.

NTT Nusa Tenggara Timur.

PLN Perusahaan Listrik Negara.

PLTBm Biomass Power Plant [Pembangkit Listrik Tenaga Biomassa].

PPA Power Purchase Agreement.

REDD Reducing Emissions from Deforestation and Forest Degradation.

SDG Sustainable Development Goal.

SEHEN Super Extra Energy Saving Electrification Program [Super Ekstra Hemat Energi].

SNM Strategic Niche Management.

SOE State-Owned Enterprises.

SPV Special Purpose Vehicle.

STR Sustainability Transitions Research.

YDD Yayasan Dian Desa (Indonesian NGO).

1 Introduction

1.1 Research Context

Climate change has been the driving force behind the global transition towards low-carbon economies. Recent analysis from the United Nations concluded that the current Nationally Determined Contributions of the Paris Agreement amount to only one third of the emissions reductions necessary to limit global warming to “well below” 2°C with respect to pre-industrial times (United Nations, 2017). They further state that it is of great importance that this emissions gap is closed before 2030. However, by 2030 the world population is expected to reach 8.5 billion people, largely driven by growth in low- and middle-income countries (LMICs) (United Nations, 2015). As per-capita energy consumption and emissions in LMICs increase towards that of high-income nations, global emissions will increase significantly (IEA, 2017). However, LMICs are characterised by high levels of poverty, limited access to sanitation services, healthcare, clean water and energy, in addition to low education rates, gender inequality, and government corruption (ADB, 2017). In these countries, human development is the primary concern. We are therefore faced with a dual challenge of human development and climate change: to limit the potentially catastrophic impacts of climate change we, as a global community, must reduce our emissions, while also reducing the huge inequalities and inequities that exist between, and within nations. Considering the need for inclusive, sustainable development in the context of climate change, *just* low-carbon transitions are of paramount importance for current and future generations.

Energy is one of the fundamental building blocks of modern civilisation. Access to energy underpins our health, life and livelihoods. Sustainable Development Goals 7 and 13 articulate the dual challenge of providing affordable, reliable and sustainable modern energy sources, while taking action against climate change and its impacts (United Nations, 2020). At the foundations of this challenge lies the concept of justice. There is a growing body of literature concerning the injustices caused by our energy systems. In the development of what is to date the most comprehensive energy justice framework, Sovacool, M. Burke, et al., 2017 discuss the injustices that arise from both fossil fuel-based and low-carbon energy systems. Even well-intentioned projects that have a net social good can have devastating impacts on vulnerable groups. For example, the expansion of coal-fired power generation to combat energy poverty in northern India has resulted in increased health risks due to increased pollution (a burden that falls most heavily on the poor communities that live close to coal mines and power plants), and an increase in child labour - some as young as nine years old (Sovacool, M. Burke, et al., 2017). Another example is solar parks in western India that promote access to clean, affordable energy, but dispossess vulnerable communities of their homes and livelihoods through land acquisition (Yenneti, Day, and Golubchikov, 2016).

The design of just energy systems must provide access to affordable, clean energy, while fairly distributing benefits and burdens. The examples above show how important the energy justice dimension is, and it leads us to question how this concept can be used to reshape our energy systems. Investigating the relationship between energy systems and justice is therefore a fundamental step in tackling poverty and climate change.

1.2 Case Study Selection

Country

Indonesia is a particularly interesting case study for low carbon transitions in LMICs due to its scale, vulnerability to climate change, and high potential for renewable energy technologies, which can alleviate many of the injustices caused by the fossil-fuel dominated electricity sector. Indonesia spans almost 2000 square kilometers, over 17,000 islands (6,000 of which are inhabited), and is home to around 270 million people (World Population Review, 2020). With 80% of its industries and 60% of its population located in coastal regions, Indonesia is particularly vulnerable to rising sea-levels and extreme weather events (Fünfgeld, 2020). Furthermore, Indonesia's agriculture sector, which currently employs 28% of the population, and is crucial for meeting domestic food demand, is particularly vulnerable to climate change: a one month delay in the monsoon season could lower crop yields by as much as 11%, while crop mortality due to higher averages temperatures could decrease yields by a further 34% (World Bank, 2020b; Krishnan et al., 2011).

Economic growth over the past thirty years has brought about a significant reductions in poverty and increases in access to electricity. Considering a poverty line of $ 3.20/day, the poverty headcount fell from 87% in 1990, to 24% in 2018 (World Bank, 2020a). The total electricity generation grew from just 33 TWh in 1990 to 283 TWh in 2018 (IEA, 2020b), increasing the electrification rate from 48.9% to 98.5% (World Bank, 2020b). Although electricity consumption, which reached 1.02 MWh per capita in 2018, has grown significantly since 1990, it is still very low in comparison to neighbouring countries like Malaysia (4.90), Thailand (2.70) and Vietnam (1.60) (pwc, 2018). The growth in electricity consumption and production has followed the structural transformation of the Indonesian economy; from agriculture and mineral extraction, towards industry and services (see Figure A.3). This economic restructuring has led to shifting populations from rural communities to industrialised cities. Electricity consumption is concentrated in the urban, industrialised regions of the country, such as DKI Jakarta where 99.99% of the people have access to electricity (DGE, 2020). However these figures can be markedly different in more rural regions such as Nusa Tenggara, where electrification rate is 85.84% (DGE, 2020). By 2018 1.5% of the 264 million people did not have access to electricity - or around 4 million people (World Bank, 2020b). However, many of the people who are considered to have access to electricity, only receive electricity for a few hours a day, and in quantities insufficient for basic needs (Sambodo and Novandra, 2019; AGECC, 2010). Therefore the actual number of people that receive access to electricity sufficient to meet their basic needs is likely to be much greater than 4 million. Improving access to reliable electricity, in sufficient quantities remains a key challenge in Indonesia.

Indonesia's development pathway has been largely fuelled by fossil fuels. Coal has dominated the electricity sector since 2000, and by 2019 it accounted for approximately 60% of production (IEA, 2020b). In 2019 84% of electricity was generated from fossil fuels, with the remainder coming from hydropower (7%), geothermal (5%), and biofuels (4%) (IEA, 2020b). The Indonesian government aims to increase the share of renewables to 23% by 2025. Despite these targets, coal has accounted for the vast majority of added capacity in recent years. Further investigation into the processes which influence the development of renewable energy technologies, and which stabilise the fossil fuel regime, is needed in order to advise how this transition can be accelerated.

Furthermore Indonesia's development path has not been an inclusive one - analysis from The World Bank shows that the majority of development over the past few decades has been enjoyed by just the richest fifth of the population (World Bank, 2014). Poor communities have received the smallest benefits from the development of the electricity sector, yet they also bear the brunt of the burdens created by the sector, which range from increased mortality and morbidity due to higher exposure to particulate matter from coal mines and power plants, to loss of livelihoods due to the environmental damage caused by energy infrastructure such as coal mines and hydropower plants (Fünfgeld, 2016). Careful consideration of justice is required to ensure that the forthcoming low carbon transition creates a more just energy system.

Renewable Energy Source

Indonesia is an agricultural powerhouse. It is the world's largest producer of palm oil, cloves and cinnamon; the second largest producer of nutmeg, rubber, vanilla, cassava and coconut oil; the third largest producer rice and cocoa; the fourth largest producer of coffee; the fifth largest producer of tobacco and the sixth largest producer of tea (World Atlas, 2019). This agricultural activity employs almost 30% of the population (World Bank, 2020b), over 75 million people, and generates enormous amounts of residues that can be used as feedstocks for power generation. This makes biomass power generation a very interesting option for Indonesia's electricity mix.

Estimates of bioenergy potential in literature vary widely due to differences in methodologies, assumptions and data sources. In a review of bioenergy potential assessments, Batidzirai, Smeets, and Faaij, 2012 found that many studies did not account for basic sustainability criteria such as land-availability and competition for water resources. The authors of this study developed an integrated analytical framework to harmonise existing bioenergy assessments. Accounting for sustainability constraints, they estimate that the potential of sustainable biomass supply is in the range 2 - 10.9 EJ/year (Batidzirai, Smeets, and Faaij, 2012). IRENA's estimate lies within this range at 3 - 4.5 EJ/year (IRENA, 2017). In IRENA's REmap scenario for Indonesia, electricity production from biomass increases eight-fold by 2030 (IRENA, 2017).

A range of solid, liquid, and gas biofuels can be used to generate power - this study will focus on the use of solid biomass. The main types of solid biomass are: perennial lignocellulosic feedstocks, first-generation crops, forestry residues, and agricultural residues (IRENA, 2017). The two main pathways used for converting the chemical energy stored in solid biomass to thermal energy, and eventually to power, are (1) direct combustion, and (2) gasification. The gasification process theoretically has a number of advantages over direct combustion; higher efficiencies, lower emissions, and the ability to operate on smaller scales (Neubauer, 2013), making it particularly interesting for LMICs that have considerable biomass resources, and that are working on increasing rural electrification (You et al., 2017).

Electricity generation from biomass has increased significantly in recent years - in 2019 the installed capacity of biomass power plants reached 1890 MW, 205 MW on-grid and 1685 MW off-grid (DGNREEC, 2019). A target of 5500 MW by 2025 is set in the national energy policy, together with an implementation plan. The actual, and planned capacities for biomass electricity in shown in Figure 1.1.

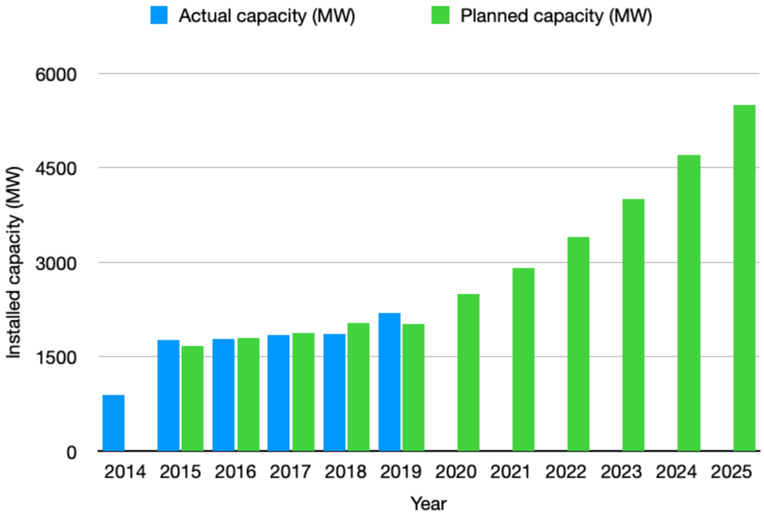


Figure 1.1: Actual and installed capacities of biomass power plants (Source: Primadita, Kumara, and Ariastina, 2020).

The capacities discussed above encapsulate a variety of conversion methods (co-combustion, direct-combustion and gasification), and sources (agricultural waste, industrial waste, manure, and municipal waste). The Directorate of New and Renewable Energy and Energy Conversion (EBKTE) publish a list of all biomass power plants (PLTBm), but do no specify whether the plant uses direct-combustion or gasification (DGNREEC, 2019). A review of biomass use for electricity generation was published on ResearchGate in July 2020 (Primadita, Kumara, and Ariastina, 2020). The authors present a list of PLTBm projects that started operating between 2011 and 2019, identifying just 2 biomass gasification plants - a 500 kWe gasifier in Gorontalo that processes corncob, and a 1 MW gasifier in West Sumba that processes Calliandra wood. The list of PLTBm power plants that the authors present is much smaller than that presented by the Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC) in their performance report (DGNREEC, 2019). Furthermore, several biomass gasification projects are not listed in one, or both of these sources. Therefore, there is currently no comprehensive list of biomass gasification projects in Indonesia.

1.3 Research Relevance

Practical Relevance

Interest in renewables has been increasing in Indonesia due to their suitability for addressing Indonesia's energy trilemma of: security (affordable and reliable supply), access (alleviating poverty), and environment (sustainability) (Setyowati, 2020a). Biomass gasification is a particularly interesting option for Indonesia due to the large potential of feedstocks in rural areas, where there is also a need to increase access to affordable, reliable electricity, and stimulate rural development. Activities in the biomass gasification niche date back to the late 1970s when oil-importing Western countries, under pressure to investigate alternative energy sources due the oil crises, conducted joint demonstration projects in rural areas in Indonesia. Despite commencing activities over 40 years ago, biomass gasification is still a relatively undeveloped niche in Indonesia, with currently very few successful projects. In this context, further investigation into the factors affecting niche development will be very useful for niche actors.

The data collected regarding niche developments has high practical value as to date there is not one source that provides a comprehensive list of biomass gasification projects in Indonesia. There is also a severe lack of publicly available information regarding the status of projects. This research addresses both knowledge gaps, and goes further, investigating the learning experiences from projects over the past forty years. This will allow actors, that have operated largely in isolation, to learn effectively from the experiences of actors outside of their project network.

The energy justice analysis, which assesses developments in the electricity sector and in the biomass gasification niche, is of high practical relevance. At the electricity sector level, energy justice analysis provides insights into how choices in electricity generating technologies impact different dimensions of justice. Whereas, analysis at the niche level provides a means to expose and mitigate any injustices caused before the niche develops further. Combined, such an analysis provides insights into if and how the niche can resolve injustices caused by the electricity sector - a finding that is highly relevant for both niche developers and policy makers. Furthermore, the broad energy justice framework applied in this research facilitates the exposure of a vast number of injustices that the Government's current energy justice analysis is blind to.

Academic Relevance

This research has two main sources of academic relevance: firstly, it contributes to the lack of Sustainability Transitions Research (STR) case studies in developing countries, in particular in Indonesia, where there are currently just four such case studies. Secondly, this research is aligned with the need to incorporate justice theory into STR studies. Indeed, despite being deeply embedded in sustainability transitions research, there has been very little explicit engagement with justice frameworks (Eames and Hunt, 2013; Hopwood, Mellor, and O'Brien, 2005; Jenkins, Sovacool, and McCauley, 2018). Furthermore, justice is often overlooked in transitions driven by sustainability concerns, despite the reality that without consideration of justice, low-carbon transitions can exacerbate inequalities in society, aggravate poverty or worsen gender bias and non-participation of marginalised groups. In early January 2019 the leading authors in STR published an agenda for the field, describing the state of the art and future directions (Köhler et al., 2019). One of the key areas for further research is the integration of justice principles into analytical frameworks - this is the main academic contribution of this research.

1.4 Research Outlook

The objective of this research is to investigate the factors that have influenced the development of biomass gasification in Indonesia, and how niche projects and the electricity sector have performed with respect to energy justice. A historical approach is adopted to gain insights into these processes since 1980, when niche development was in its infancy. One of the implications of integrating energy justice into sustainability transitions research is that the study will have not have one focus, but two - *energy justice*, and the *factors* that have influenced niche development. The main research question therefore has two dimensions - one for each focus point. The main research question is divided into three sub-questions; each of which provide a piece of the final answer.

Main Research Question

What are the main factors that have influenced the development of biomass gasification in Indonesia since 1980 and how has the niche contributed to energy justice?

Sub-Research Questions

1. How can transition frameworks and justice theory be combined to study the biomass gasification niche?
2. How has the electricity regime performed with respect to energy justice?
3. How has the biomass gasification niche performed with respect to energy justice?
4. What are the main factors that have influenced the development of the biomass gasification niche?

Chapter 1 has focused on introducing the research and explaining its practical and academic relevance. The theory behind several sustainability transitions research frameworks is described in Chapter 2. Chapter 3 subsequently uses this theory to develop an analytical framework, addressing Sub-Question 1. Chapter 4 introduces some useful background information regarding biomass gasification. Chapters 5 through 7 address Sub-Questions 2, 3, and 4 in an integrated manner for three defined time periods, 1980 - 2005, 2006 - 2016, and 2017 - 2020. Chapter 8 reflects on the research design, methodology, and academic and practical contributions. Chapter 9 brings together the findings from Chapters 5 through 7 to answer the research questions. Finally, recommendations for regime and niche actors are presented in Chapter 10.

2 Theoretical Background

This section will first discuss the theoretical underpinnings of the Multi-Level Perspective, Strategic Niche Management and the energy justice frameworks. Attention will be given to several important insights from the application of these frameworks to developing countries, including: experiments and upscaling, transnational linkages, power and path-dependence (Wieczorek, 2018). This section will close with a brief discussion of academic relevance.

2.1 Multi-Level Perspective

The most prominent framework for analysing sociotechnical transitions is the Multi-Level Perspective (MLP). This framework was developed by Frank Geels using insights from evolutionary economics and technology studies (Frank Geels, 2002). In evolutionary economics, technological evolution can either occur through a process of variation, selection and retention; or through an iterative unfolding process which creates a path or trajectory over time. The idea of selection is that new innovations are chosen by users, however, there is often not an existing market. New innovations must therefore co-evolve with their markets, and user preferences. Geels expands the idea of selection to a wider environment that includes not only users and markets, but policies and institutions. From technology studies, Geels incorporates the idea that interlinkages between technologies and social elements create stability in a system.

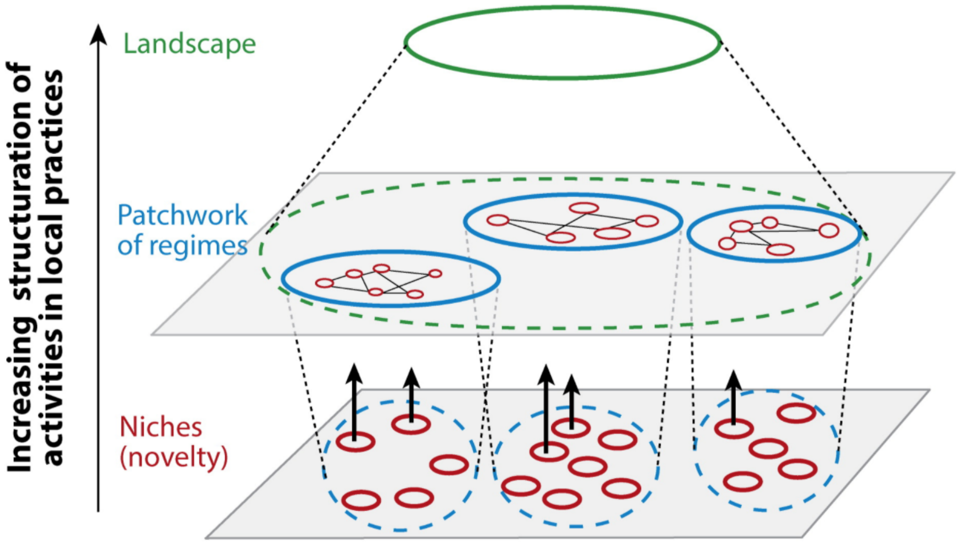


Figure 2.1: The nested multi-level perspective on socio-technical transitions (Source: Loorbach, Frantzeskaki, and Avelino, 2017).

The MLP conceptualises transitions as non-linear processes that are driven by interacting developments on three nested levels (Figure 2.1): niche innovations (red), the regime (blue), and the landscape (green). Each conceptual level corresponds to a different scale; the niche is the micro-level, the regime is the meso-level, and the landscape is the macro-level.

The sociotechnical regime encompasses the dominant technologies, infrastructures, institutions, policies, markets, user practices, and culture (Frank Geels, 2002). The regime can be divided into three interlinked dimensions: (i) the network of actors, (ii) the set of rules that guide the activities of actors, and (iii) the technology and materials (G. Verbong and F. Geels, 2007). In the electricity sector the main actors are government ministries, utilities, industrial users, and households. Laws, regulations and belief systems are examples of rules that guide actor activities. The last term refers to the technology and materials required for the generation, transmission, and distribution of electricity. Stability is created through the interactions between these three regime dimensions, and leads to path-dependence or lock-ins. Lock-ins can be techno-economic, social-cognitive, or institutional and political (Frank W Geels, 2019). Techno-economic lock-ins occur because actors have vested interests in the incumbent regime - human and physical capital has been committed in the form of competencies (employees, training), power plants, and supporting infrastructure. Substantial investments in development over many years has drastically improved the price-performance of the existing technologies - this is an investment that incumbents stand to lose in a transition. Lock-ins can also be caused by the social/cognitive rules that govern actors - actors within a regime share routines and mind-sets that can blind them to alternatives, the alignment and organisation of large social networks is analogous to investments in physical and human capital that also stand to be lost in the case of a transition, and finally the lifestyles of end users can be become built around certain technologies (however this is less relevant for the electricity regime as end users are insulted against the changes in generation caused by renewables). Lastly, lock-in may also be caused by the formal rules that govern actors - regulations and policies support the existing configuration of organisations, resources, and technologies. Powerful regime actors can also also influence the regulatory environment by lobbying the government - for example, the five largest publicly owned oil and gas companies spend \$ 200 million *every year* on lobbying governments to alter, delay and block climate policy (McCarthy, Niall (Forbes), 2019). In summary, the interlinkages between these three regime dimensions (rules, networks, and technologies) creates stability, and in some cases lock-ins (socio-technical, socio-cognitive and institutional and political), which severely limit the *speed* of change processes and impose a *direction* upon transitions, favouring the success of the dominant regime members (G. Verbong and F. Geels, 2007; Markard, Rob Raven, and Truffer, 2012; Frank W Geels, 2019).

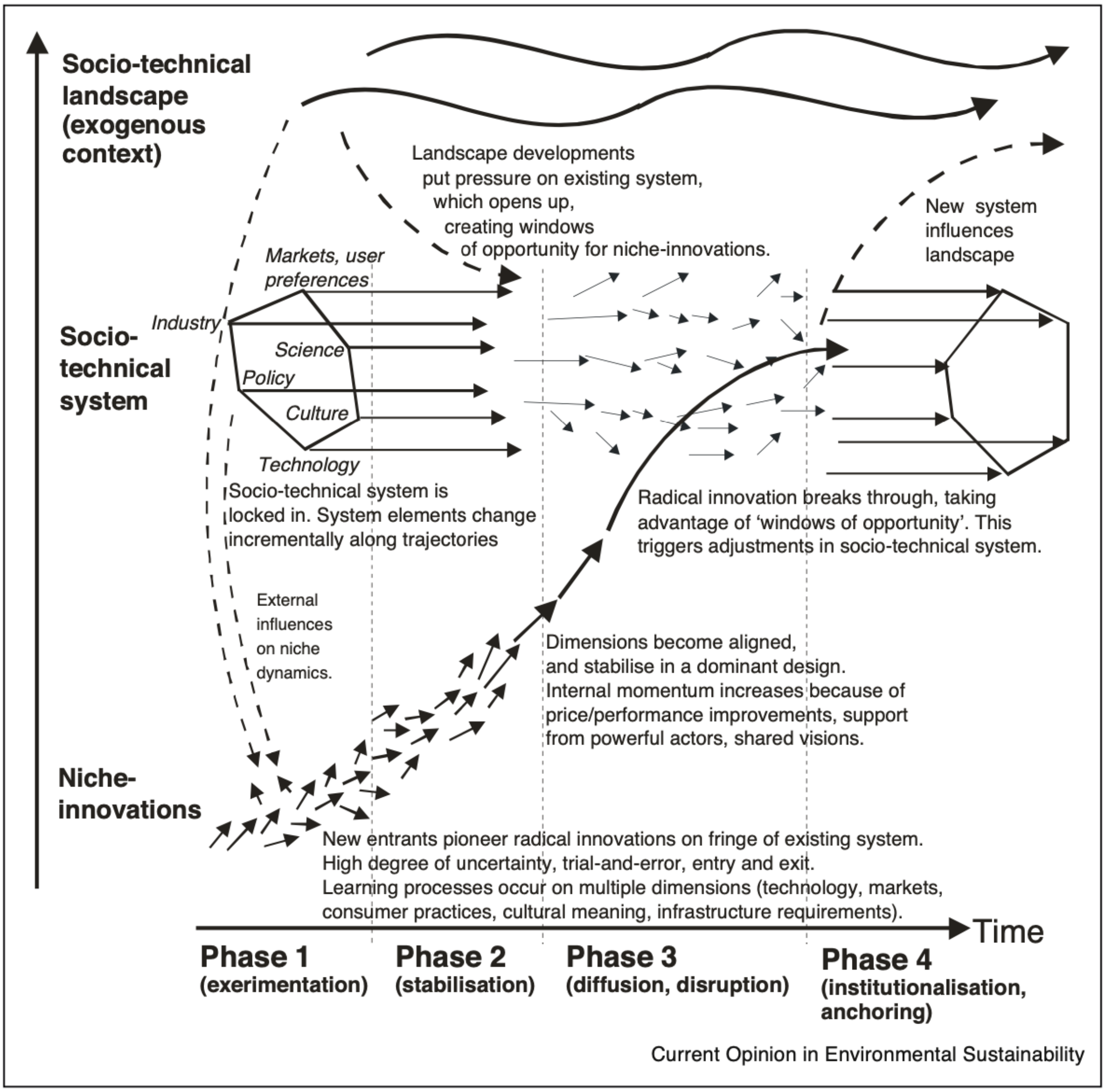
The niche is the bottom level of the MLP, conceptualised as protected spaces within which new innovations can grow outwith the selection pressure of the incumbent regime. Selection pressures constitute the rules that dictate the success (or failure) of technologies in the regime - for example, in electricity regimes the economic performance of a power plant (\$/kWh) determines when, and how much electricity the plant can sell in the spot market, which in turn dictates whether the plant will be able to generate sufficient returns over its lifetime. As new innovations typically exhibit poor price/performance ratios it is important that these are allowed to develop in these protected spaces.

The top level in the MLP framework, in which the other levels are nested in, is the landscape (Figure 2.1). This level accounts for changes on a much larger scale than the niche and regime levels. Slow-moving macro-trends such as demographics (age, education, employment, income), politics (nature of political regime, structuring of society), and macro-economic trends (GDP, shifts in import/export, inflation) are considered in addition to shock events such as wars, financial crises, commodity price shocks (Smith, Stirling, and Berkhout, 2005; Frank Geels, 2002; Frank W Geels, 2019). The position at the top of the MLP indicates that these large scale landscape developments influence the regime and niche levels in a *predominantly* unilateral manner.

Transitions in socio-technical systems are thought to be a result of interactions between processes at all three levels of the MLP: niche-innovations build up momentum (improving performance and support) through experimentation and networking which, together with landscape developments, puts pressure on the incumbent regime (Frank Geels, 2002; Frank W. Geels and Schot, 2007). The destabilisation of the regime creates ‘windows of opportunity’ for niche-innovations to diffuse into the regime (Frank W Geels, 2019).

The MLP divides transitions into four phases: (1) experimentation, (2) stabilisation, (3) diffusion & disruption, and (4) institutionalisation & anchoring (Figure 2.2). The first stage begins with actors performing R&D experiments on the niche-innovation, which allows actors to build up some understanding of the technological characteristics of the innovation. These early experiments eventually progress to small-scale demonstration projects, which places the innovation in the socio-technical, socio-economic, and socio-cultural context, allowing actors to gain insights into how the innovation performs outside of the lab. The many small arrows pointing in different directions in Figure 2.2 indicate that this stage is characterised by many iterations and small-scale experiments (high uncertainty). The challenge is to move from fragmented experiments and initiatives that are typically short-lived towards the second stage, where innovations stabilise and settle into a market niche (Frank W Geels, 2019).

As the variation in design decreases, the fragmented experiments start to build on one another through the sharing of experiences, development of best practices and guidelines. Communities of specialists, associations and various agencies can facilitate the spread of knowledge and can even help to convert the learning experiences from independent experiments into shared general lessons, accessible for all niche actors. This process of knowledge aggregation stabilises niche development. As the wider society gain exposure to the niche-innovation, the articulation of experiences and visions can be very influential, especially by reputable/visible actors - positive visions can help to legitimise the innovation and attract support, whereas negative visions can create doubt, uncertainty and can stall development (e.g. public opposition to wind turbines - lawsuits, delays, demonstrations (Geraint and Gianluca, 2016)).



Current Opinion in Environmental Sustainability

Figure 2.2: The multi-level perspective of socio-technical transitions (Source: Frank W Geels, 2019).

The third stage is a critical one - once the socio-technical/economic/cultural performance of the innovation has improved and the niche has attracted a larger number or powerful supporting actors, the niche-innovation is ready to diffuse into the incumbent *destabilised* regime. This phase is characterised by rising tensions on the different dimensions of the regime in response to increased diffusion of the niche-innovation - for example economic tensions arise when renewable energy technologies undercut all incumbent with zero bids in the spot market, ensuring they sell electricity at all times, which also creates political tensions as struggling incumbents put pressure on the government to change regulations, policies, subsidies, or even reshape the wholesale electricity market into a capacity market (European

Commission, 2016). Tensions in this phase involve a growing number of powerful actors and sparks intensifying public debates.

The fourth and final stage of the transition is when a new socio-technical system (perhaps comprising of multiple niche-innovations, such as solar PV and wind turbines) becomes institutionalised and anchored by the different regime dimensions, replacing part of the old regime.

2.2 Strategic Niche Management

The MLP's focus on the regime level can come at the expense of understanding processes at the niche level. To compensate for this, the MLP is combined with the Strategic Niche Management (SNM) framework. SNM theory was developed in the late 1990's to investigate the transition to sustainability through analysing the development of innovative technologies within niches (Kemp, Schot, and Hoogma, 1998). Niche innovations are *shielded* from the selection pressures of the regime, they are then *nurtured* through three mutually reinforcing internal niche processes (voicing expectations, network formation, and learning processes), and finally they can be *empowered* by a various activities and actors which, in combination with landscape pressures and subsequent regime developments, allow the niche to diffuse into the regime.

Niche Shielding

The socio-technical regime consists of established industries, technologies, markets, users, and networks, and are governed by existing formal, normative and cognitive rules rules (Figure 2.2). Innovations develop in niches that *shield* them from the selection pressures of the existing regime (Frank W. Geels and Schot, 2008). This shielding may be active, or passive.

Passive spaces are those within which selection pressures are less intense than in the mainstream regime. Rural areas are geographical spaces in which the selection pressures for electricity generation are felt less intensely; primarily due to the lack of electricity distribution infrastructure, however, other factors can also contribute to this passive shield, such as the smaller size of incumbent actors within the space. Niche spaces can also be created actively through regulations, tariffs, and taxes (e.g. Feed-in-Tariffs and a carbon tax), which counter-act characteristics of the niche that would make them noncompetitive with existing technologies (i.e. price-performance), but also through information campaigns, portfolio standards/quotas, and market segmentation which aim at changing preferences. In addition to policy actors, niches can be shielded by initiatives from the private sector (e.g. subsidiaries of incumbent regime actors) and civil society (e.g. cooperatives). Smith and Rob Raven, 2012 list several examples of how niches can be shielded from the selection pressures arising from the various pillars of the socio-technical regime - user relations, knowledge, policies, etc. Once the niche is embedded in a protected space it must be *nurtured*.

Niche Nurturing

The nurturing process is seen as a combination of three mutually reinforcing processes: (1) the voicing and shaping of expectations, (2) iterative learning processes, and (3) the formation of an actor network (R.P.J.M. Raven, 2005).

The niche is formed when the promise of a new technology is aligned with a societal need, for example a sustainable energy technology that is aligned with the societal need for clean energy. The voicing of expectations gives direction to the product's development and so influences choices in design and attracts new actors. Much alike constructive interference, the more in-phase, or coherent, the expectations of actors are, the greater the development of the overall niche. Consider the case when actors have different expectations: experiments of different actors do not contribute to a shared knowledge base or reinforce the experimental findings of the other actors.

Further development of the niche comes through experimentation, where actors learn more about the technological and societal possibilities, as well as the constraints such as performance and public acceptability. Hoogma, Weber, and Elzen, 2005 define several aspects of the learning process: technology and infrastructure; understanding of user context; health, safety and environmental impact; production and maintenance networks; and finally learning about the policy and regulatory environment. As the technology develops over time through experimentation and learning, social actors gain more exposure to the technology, and their expectations of it evolve (reshaping of expectations). Expectations also shift over time as a result of developments at the regime and landscape levels (Kemp, Schot, and Hoogma, 1998); an example of this is an oil crisis creating renewed interest and urgency around renewable energy development. As the technology develops further still, expectations become more coherent and accurate, supported by experimental evidence (R.P.J.M. Raven, 2005). However, it is common in well-defined systems such as energy and infrastructure where there is less room for creativity, niche innovations may also arise from specific visions (Turnheim and Frank Geels, 2019). Such innovations could benefit from a more guided development journey.

Throughout this process, a network of interacting actors is built up. Actor networks sustain and expand development by voicing and shaping expectations, learning, and attracting resources and new actors. Actors could have varying expectations, strategies, values and motivations for their involvement and as such, the composition of the actor network, and the harmony between these actor characteristics can be a determining factor in the success of the innovation, this is called actor alignment (Hoogma, Weber, and Elzen, 2005). In addition to alignment, it is deemed beneficial for the network to comprise of actors with a range of different interests and (complimentary) roles. In their study on the development of small wind turbines in Kenya, Kamp and Vanheule, 2015 also analyse the quality of sub-networks, which are groups of stakeholders with similar roles within the larger niche network such as researchers, or companies. The network composition, size and roles of each actor within the network and sub-network change over time and influence the performance of the network (Kemp, Schot, and Hoogma, 1998). Although it was previously thought that the interaction between niche and regime actors was minimal, studies have shown that incumbent regime actors can support niche growth through the supply of resources (Diaz et al., 2013), or through networking, certification, regulatory support/exemption (Ingram et al., 2015). Incumbent regime actors can not only support niche development but also re-orientate towards niche innovations (Bergek et al., 2013; Penna and Frank W. Geels, 2015).

In SNM literature there has been several changes in perception regarding the role of individual projects. Early researchers emphasised the importance of individual projects as hubs for these internal niche processes (Kemp, Schot, and Hoogma, 1998). However, a revealing case study of electric vehicles by the same authors in 2002 suggested that projects did not have a strong influence on actor decisions (investing in further development), and that the feedback loops through which an innovation develops and diffuses into the mainstream are much weaker and slower than originally thought (Hoogma, Kemp, et al., 2002). Frank Geels and Rob Raven, 2006 later introduced the idea that local niches contributed to the global niche - learning experiences and expectations are communicated to a wide audience of actors who interact on a global level (Figure 2.3). This is particularly relevant for renewable energy technologies such as biomass gasification, as bi-lateral and multi-lateral organisations have played a major role in facilitating early experimentation and demonstration in developing countries. As the global niche is an aggregation of local experiences, the body of experimental data accumulates much faster than on the local level and contributes to the refinement of expectations (and increasing quality), which creates stability.

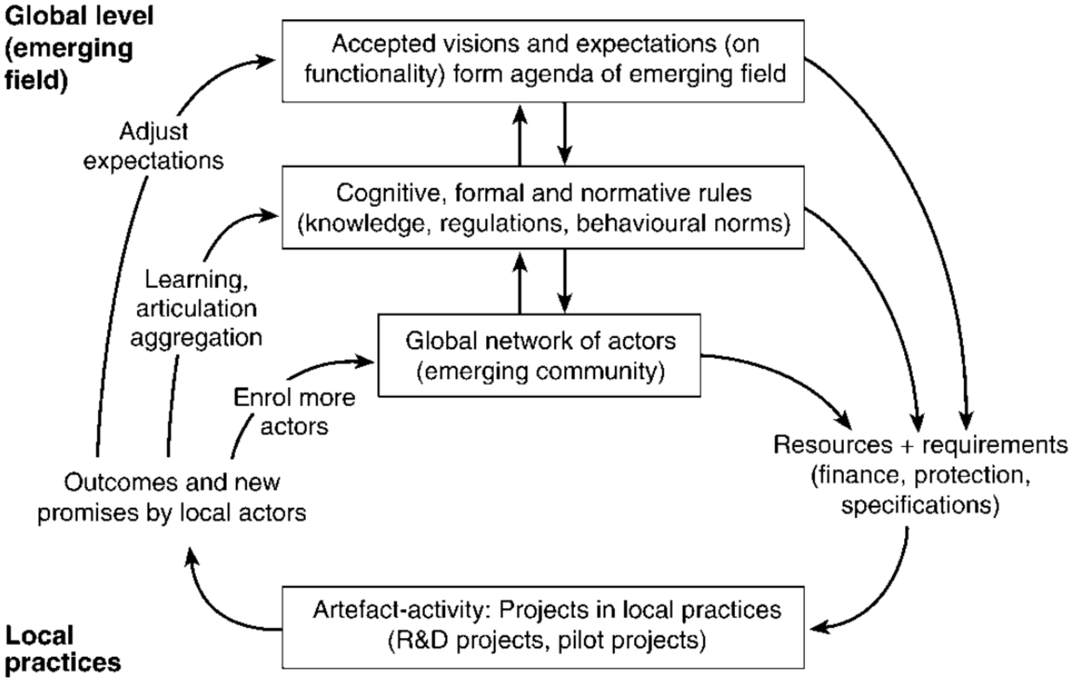


Figure 2.3: The interaction between local and global internal niche processes (Source: Frank Geels and Rob Raven, 2006).

Niche Empowerment

After nurturing, empowerment is the next step in niche development, which sees the niche transition from it's protected space into the mainstream regime environment, where it will interact with the different dimensions of the socio-technical regime. Contrary to MLP conceptualisations of regime change, whereby landscape factors destabilise regimes and create 'windows of opportunity' for niches, recent SNM literature suggests that niches too can exert pressure on the regime. This pressure is articulated through 'empowerment' activities that are carried out by coalitions of niche actors. These activities aim to increase the competitiveness of niche innovations; depending on the nature of these activities, the niche can either 'fit and conform', or 'stretch and transform' (Smith and Rob Raven, 2012).

The first type of empowerment, fit and conform, makes niche innovations competitive in the existing regime, without changing any of the selection pressures of the regime. Without any changes to the selection environment in the regime, the impact of any niche innovation entering is limited to one of incremental improvement. The niche innovation, that was once considered to potentially disruptive and transformative, becomes almost dis-empowered by conforming to the selection environment of the incumbent regime. However this is not necessarily a negative pathway - a potentially radical niche innovation, for example solar PV, could become competitive through empowerment activities and enter a regime without any significant changes to the selection environment. However, once landscape pressure, such as climate change, causes the regime selection environment to change (for example through the implementation a carbon tax, or portfolio standards), the niche innovation that has already become competitive in the old regime, will now start to dominate.

Empowerment activities can alternatively aim to change the selection of the regime in favour of the niche innovation. Once the selection environment has changed, this will encourage the development of more sustainable innovations and so can have a much more transformative effect on a regime transition than fit and conform pathways. This process is unlikely to occur entirely within the niche as it involves changes to the regime selection environment. The stretch and transform pathway therefore requires sustainability advocates to be able to influence political actors to institutionalise aspects of sustainability. It is important that the niche innovation is sufficiently developed/empowered and represents a viable solution to the increased pressure on the regime.

2.3 Energy Justice

STR frameworks like the MLP and SNM have sought to understand the processes by which sustainability transitions occur, and how niche innovations develop - providing valuable insights into how these can be enhanced and accelerated. However, despite being at the very foundations of sustainability, STR literature to date has had very little explicit practical engagement with justice theory. The integration of justice theory in this research is a key source of practical and academic relevance.

The theory of energy justice stemmed from environmental justice that is concerned with the access to natural resources, the distribution of environmental hazards and meaningful involvement in decision-making, and fair treatment in access to benefits (Schlosberg, 2009). The roots of energy justice can also be seen in the 'three-A's' principles introduced in 2007 by the Asian Pacific Energy Research Centre: availability, accessibility and affordability (Asia Pacific Energy Research Centre, 2017). In their book on global energy justice, Sovacool and Dworkin define an energy just world as:

"One that equitably shares both the benefits and burdens involved in the production and consumption of energy services, as well as one that is fair in how it treats people and communities in energy decision making" (Sovacool and Dworkin, 2014, p. 5).

This lays the foundations for energy justice frameworks, which describe the principles of an energy just world. Much of the literature focuses on three core tenets of justice: distributional, recognition and procedural. McCauley et al., 2019 add cosmopolitan and restorative justice to this list of core tenets.

Distributional justice: globally, energy systems unevenly distribute their benefits and their ills in space and in time. Fraser, 2003 identifies several levels of distributional injustices; exploitation, marginalisation and deprivation. Relating these to the energy system exploitation could concern the use of human capital and natural capital to provide energy services to others, while the exploited also bear the burden of local environmental damage. Marginalisation could refer to being confined to poor quality energy services (such as rural communities), whereas and deprivation could entail being denied energy services all together. Low-carbon energy infrastructure can be just as damaging to social justice - careful consideration of justice principles is needed to ensure that the low-carbon transition is a just one. One such example is the use of wind turbines in Europe, which reduces the point of use emissions for electricity production in Europe, however, approximately 80% of the embodied emissions and environmental damages associated with these turbines were exported to China and Korea, where they were manufactured (Sovacool, Perea, et al., 2015). In this example, the benefits of the wind turbines (low cost renewable energy) are enjoyed by Europeans, while those living near to the manufacturing sites in China and Korea bear the majority of the ills (local air emissions).

Recognition justice: understanding which inequalities emerge from energy systems, and where they emerge, leads to the identification of energy victims; those in society who are worse affected by the energy system. Larger social patterns of representation, interpretation and communication are at the root of recognition injustices (Fraser, 2003). Fraser further classifies three types of misrecognition; cultural domination, nonrecognition, and disrespect. While the latter two terms are self-explanatory, cultural domination refers to forcing patterns of interpretation and communication, that are specific to one party's culture, on the other party. Low-carbon energy systems in particular involve such a high degree of multi-cultural collaboration and so consideration of such cultural domination is very relevant and important.

Procedural justice: everyone has the right to a fair process. The identification of distributional injustices and (mis)recognition of victims is not sufficient to form just energy systems; it must be linked to a practical tool for achieving energy justice. Procedural justice requires full recognition of those affected, consideration of alternative locations and practices, and involvement in delivering a more equitable outcome (Jenkins, Sovacool, and McCauley, 2018). Procedures may be formal or informal. Formal procedures, involving the legal system, are relatively easy to analyse, whereas informal processes are more challenging to identify and analyse as they also embody cultural norms and values.

Cosmopolitan justice: principles of justice apply to all human beings who are part of a singular community based on a shared moral code. As the negative impacts of energy systems reach far beyond national borders to have global impacts, the responsibilities for these systems are also global in scope.

Restorative justice: energy systems can impose significant damages to people and the environment locally and globally, a just transition would not only recognise these injustices, but also provide the solutions necessary for repairing these damages. For example, the closure of coal mines will lead to thousands of unskilled laborers losing their jobs. These people will likely not have the competencies required to support the renewable energy business with their labour. Restorative justice measures should consider how these people can be compensated for their loss of employment, such as competency training or financial support. The Coal and Electricity Transition Tuition Voucher, is an example of such a restorative measure which provides access to subsidised post-secondary education for retraining coal workers in Alberta and Victoria, Canada (Alberta Government, 2020).

In 2016 several leading authors in this field attempted to address the need to better operationalise energy justice theory into a framework that could be easily used by energy analysts and decision-makers - a key step to creating more just and equity energy systems (Sovacool, Heffron, et al., 2016). The authors synthesize an eight principle framework through consideration of the core justice tenets described above - distributional, recognition, procedural, cosmopolitan, and restorative justice. **Each principle therefore embodies either one, or a combination of these core justice tenets**. The framework, however, failed to address the fact that much of the energy justice literature to date has been dominated by Western and anthropocentric views of justice. A later work from Sovacool aimed to expand the existing framework through consideration of non-Western theorists, and non-anthropocentric perceptions of our energy systems (Sovacool, M. Burke, et al., 2017). The extended ten principle framework for energy justice is shown below in Table 2.1.

Although the first eight principles shown above are perhaps easily understandable, the reader would benefit from a brief elaboration of the final two terms - *resistance* and *intersectionality.* The introduction of *resistance* to the energy justice framework is a result of non-Western and non-anthropocentric justice theory which states that unjust, oppressive projects that violate justice principles must be actively and deliberately resisted (Sovacool, M. Burke, et al., 2017). An example of this *resistance* is public protests and demonstrations against the coal mining and coal power projects in East Kalimantan that have had immense negative impacts on human and non-human life. *Intersectionality* refers to the intersection of justice concerns and principles. It recognises that at the root of energy justice theory, is social justice, and that these concepts are deeply intertwined - the characteristics of our energy systems have a wide range of implications for social justice concerns: from economic justice, to gender and race inequality (Sovacool, M. Burke, et al., 2017). Adopting *intersectionality* also allows for the consideration of victims to extend beyond humans - this non-anthropocentric view is crucial for this case study as Indonesia is one of the most biodiverse countries in the world.

It is important to note that these principles do not necessarily align with each other - in each decision there are trade-offs. Consider the example of large scale coal power plants in India that significantly increase the supply of and access to electricity - this has a positive impact on the *availability* of energy services, *intragenerational* justice as people who were previously marginalised by poor access to energy services gain access, and perhaps also *affordability* since production costs from large coal plants (in the absence of carbon pricing policy) is relatively low. However, the lack of *due process*, opaque activities, high levels of land, water and air emissions, suppression of public *resistance* to injustices, and the fact that poor communities bear the brunt of the negative impacts of these power plants means that they perform poorly with respect to principles 3, 4, 5, 7, 8, 9, and 10. By considering how different energy infrastructures impact each principle of energy justice one can build an understanding of the trade-offs involved in each option.

Table 2.1: Conceptual framework of ten energy justice principles (Source: Sovacool, M. Burke, et al., 2017).

No.	Principle	Description
1	Availability	People deserve sufficient energy resources of high quality (suitable to meet their end uses)
2	Affordability	All people, including the poor, should pay no more than 10% of their income for energy services
3	Due Process	Countries should respect due process and human rights in their production and use of energy
4	Transparency and accountability	All people should have access to high quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making
5	Sustainability	Energy resources should be depleted with consideration for savings, community development, and precaution
6	Intragenerational equity	All people have a right to fairly access energy services
7	Intergenerational equity	Future generations have a right to enjoy a good life undisturbed by the damage of our energy systems inflict on the world today
8	Responsibility	All actors have a responsibility to protect the natural environment and minimize energy-related environmental threats
9	Resistance	Energy injustices must be actively, deliberately opposed
10	Intersectionality	Expanding the idea of recognitional justice to encapsulate new and evolving identities in modern societies, as well as acknowledging how the realization of energy justice is linked to other forms of justice e.g. socio-economic, political and environmental

At the niche level the exposure of injustices is an important first step to ensuring further development is *just*, while the identification of justices can help actors to frame innovations as solutions to injustices created and reinforced by the incumbent regime. At the regime level energy justice analysis provides a means for policy actors and others alike, to critically assess how the current socio-technical configuration of the incumbent regime impacts justice - identifying regime dimensions or activities that contribute positively to energy justice, and those which create injustices, thereby providing an opportunity to re-evaluate the selection criteria for our energy systems (Jenkins, Sovacool, and McCauley, 2018). Much like the MLP conceptualisation of transitions, the exposure of injustices caused by the regime creates 'windows of opportunity' for niche technologies that can alleviate these injustices. Finally, at the landscape level, political framing of justice by a range of stakeholders provides a means of pressuring policy actors to address the injustices of the incumbent regime (Jenkins, Sovacool, and McCauley, 2018). Using the example of climate change, two recent studies have described how local, national, and global actors can exert pressure on the regime through social, political, and economic channels (Morone et al., 2016; Kuzemko et al., 2016).

2.4 Application of Theory in Literature

This subsection will provide an overview of sustainability transitions research (STR) specific to the Indonesian context, STR related to biomass energy (globally as well as studies specific to Indonesia), and STR related to energy justice. SCOPUS was used as the main search engine due to its suitability for building lists and analysing search outputs. Searches were performed by combining keywords with AND/OR operators. Preliminary search results were reviewed and refined, omitting irrelevant documents.

The first search sought to find documents that relate STR frameworks to biomass energy in the Indonesian context. These searches returned zero results, meaning there has not been a study which investigates biomass energy in Indonesia using one of the frameworks from the STR field.

The next search performed was for documents that relate STR to renewable energy in Indonesia. The term "biomass" was relaxed to "renewable energy" and a search was performed for "strategic niche management", "functions of innovation systems", and "multi-level perspective", in addition to the country context "Indonesia". No documents were found relating to SNM or FIS. The search relating to the MLP returned four documents; two which concern the development of a particular technology (one for biogas (Bößnera et al., 2019) and one for geothermal (Wisaksono et al., 2018)), and two studies which describe the multi-level governance challenge in Indonesia (Jens Marquardt, 2014; J. Marquardt, 2016). These documents provide a useful overview of the multi-level challenge of developing renewable energy technologies in Indonesia. All four works utilise theory from sustainability research to investigate transition dynamics in specific cases (the book from Marquardt can be considered two very detailed case studies (J. Marquardt, 2016)). The studies from Marquardt and from Bößnera conduct semi-structured interviews to collect primary data for exploring the complexities of the current situation. This contrasts to the approach from Wisaksono et al., who analyse literature and secondary documents regarding past developments.

The penultimate search was for all documents relating to both STR and biomass energy. After removing irrelevant documents that mentioned "biomass" but actually concerned cookstoves, biogas, or forestry, thirteen documents were left. These documents mention "biomass" energy and either "strategic niche management" or the "multi-level perspective". These documents present some differences in their outlook, methodology, and data collection. In terms of frameworks eights studies used a single framework (five using the multi-level perspective and three using strategic niche management), while the remaining five studies used a combination of two frameworks; four of which combined the multi-level perspective with strategic niche management, and one which combined the multi-level perspective with the functions of innovation systems. The motivation for the study also varied, from using theory to investigate a specific case study, to using a specific case study to build upon existing theory within transitions research. Five of the thirteen studies aimed at developing theory with respect to: multi-regime dynamics (Sutherland, Peter, and Zagata, 2015; Rob Raven, 2007), donor interventions in niche developments (Hansen and ygaard, 2013), multi-scalar MLP (Rob Raven, Schot, and Berkhout, 2012) and boundary crossing innovations (R.P.J.M. Raven and G.P.J. Verbong, 2009). The last notable differences was in the time framing of studies and the methods of data collection. Eleven of the thirteen studies performed a historical analysis of transitions, while the focus of the remaining two studies was on the current situation (Miedema, Van Der Windt, and Moll, 2018; Burnham et al., 2017). These studies, in addition to two others (Sun and Xi, 2012; Hansen and ygaard, 2013), collected primary data through semi-structured interviews. The remaining studies relied on data available from books, articles, reports, journals, etc.).

Two of the studies identified in the last search are particularly relevant for this thesis project. Firstly, Romijn, Rob Raven, and Visser, 2010 investigated the theoretical differences between learning-based development approaches and the strategic niche management approach by looking at four biomass energy experiments in India. They conclude that the strategic niche management framework could be enhanced by incorporating insights from learning-based development approaches that enable closer consideration of local management, stakeholder organisation and the differences in power within the actor network. In the second study Geert Verbong, Christiaens, et al., 2010 studied the development of biomass gasification in India using the strategic niche management framework. Using this framework they concluded that expectations of biomass gasification were generally too high and that the technology should be embedded in a stable institutional setup to facilitate effective learning processes. Their second conclusion from this case study was that the niche diffusion was limited by regime instability, and not regime stability which the theory would suggest. Regime instability in this case undermined investor and consumer confidence.

The final search sought to identify STR articles that engaged with energy justice theory. A SCOPUS search for "multi-level perspective AND energy justice" revealed that there are no published case studies integrating energy justice into STR - the case study presented in this thesis is therefore the first of its kind.

2.5 Conclusion

This section has described the theoretical background of the MLP, SNM, and Energy Justice frameworks. The MLP introduces three nested levels - the landscape, regime, and niche - and sees transitions as the result of interactions between these three levels. SNM theory is focused on the niche level - seeing niche development as the result of shielding, three mutually reinforcing nurturing process, and empowerment. The focus of SNM lies in the analysis of the nurturing processes - network formation, learning processes, and the voicing and shaping of expectations. The integration of the SNM framework into the MLP facilitates a deeper analysis of development processes at the niche. Addressing the lack of explicit practical engagement with justice theory in sustainability transitions research, this study combines an energy justice framework with an integrated MLP-SNM framework. Energy justice theory has been built around three, or more recently five, core tenets of justice - distributional, recognition, due process, restorative, and cosmopolitan. Through consideration of non-Western philosophers and non-humans, Sovacool and his colleagues have constructed a ten principle Energy Justice framework that facilitates a more explicit and comprehensive analysis of justice relating to our energy systems.

To date, STR has had minimal engagement with both the Indonesian case, and with energy justice theory. This chapter has described the theoretical background and compatibility of the MLP, SNM, and Energy Justice frameworks. The following chapter will discuss how these are combined into one analytical framework, and how each are operationalised.

3 Research Design and Methodology

This research has utilised several methodologies: literature review, desk research, and interviews. In development of this research project the literature review methodology was used to survey the current state of sustainability transitions research, and the current state of the biomass gasification niche in Indonesia. The literature review on sustainability transitions research led to the identification of key authors, theories, and research agendas. To ensure academic relevance, the research framework developed in this thesis was centred around an area of sustainability transitions research in need of further development - incorporating energy justice into transition studies. Data for both reviews was collected primarily using keyword searches in SCOPUS (the world's largest abstract and citation database of peer-reviewed literature), but also used Google Scholar. For the review of biomass gasification in Indonesia, data collection was broadened using keywords searched in Google to include technical reports from various stakeholders including government ministries, foreign aid agencies, project developers, and newspaper articles. The main body of the research was performed by desk research, and complimented by a series of semi-structured interviews.

3.1 Research Approach

This research uses an integrated MLP, SNM, and EJ framework to analyse the transition in a specific case study. The benefit of such 'case study' designs is the ability to discover wide range of social, cultural and political factors that are related to a specific phenomenon - in this case the development and diffusion of a technology. This study combines explanatory and descriptive research (describing and explaining niche dynamics within the context of the regime and landscape levels), with exploratory research, for which stakeholder interviews will be used to gain insights into the interaction between, and expectations of actors, in addition to the impacts of developments on energy justice. The analysis for the explanatory/descriptive research is predominantly qualitative and so the output of the study largely depends on the observational ability of the researcher. However, it will be possible to validate much of the analysis with external research. The exploratory research will use interviews to supplement the desk research on the niche level and uncover stakeholder perceptions about energy justices and injustices relating to the electricity sector, and to the biomass gasification niche.

3.2 Analytical Framework

Central to this thesis is the framework through which transition dynamics and energy justice are investigated. This project combines the theory from three conceptual frameworks; the MLP, SNM, and Energy Justice. Figure 3.1 shows the dynamics of the three nested levels of the MLP; the landscape (green), the regime (blue) and the niche (red).

The three nested levels conceptualised by the MLP framework form the foundation of the analytical framework developed for this research. The SNM framework is added to the bottom level of the MLP (red) - replacing the MLP niche analysis. The SNM framework is used to analyse niche developments with respect to shielding, nurturing (voicing of expectations, learning processes, and network formation), and empowerment activities. Finally, the electricity regime and niche projects are assessed with respect to the ten principles of energy justice described by Sovacool, M. Burke, et al., 2017. Minor adjustments are made to the SNM analysis to prevent overlaps with the energy justice analysis.

The integration of the MLP and SNM frameworks is relatively straightforward as the SNM framework can replace the niche level analysis of the MLP. This is uncomplicated for the analysis of niche developments, however, some clarification is required when considering the transition dynamics as the MLP and SNM frameworks conceptualise transitions differently. The SNM framework views transitions as a result of empowerment activities, where niche innovations gain competitive advantage in the market either through improved price-performance (e.g. increased R&D), or through a changed selection environment (e.g. carbon tax). In the SNM framework there is no consideration of larger scale dynamics in the regime and exogenous environment. The MLP conceptualises transitions as a result of interactions between the three nested levels - landscape pressures cause tension in the regime, which creates 'windows of opportunity' for niche innovations to diffuse into the regime. Contrary to SNM literature, the niche does not necessarily need to be well-developed in order to break into the regime as this can occur as a result of massive shocks on the landscape and regime levels. This integrated framework adopts the MLP conceptualisation of transitions.

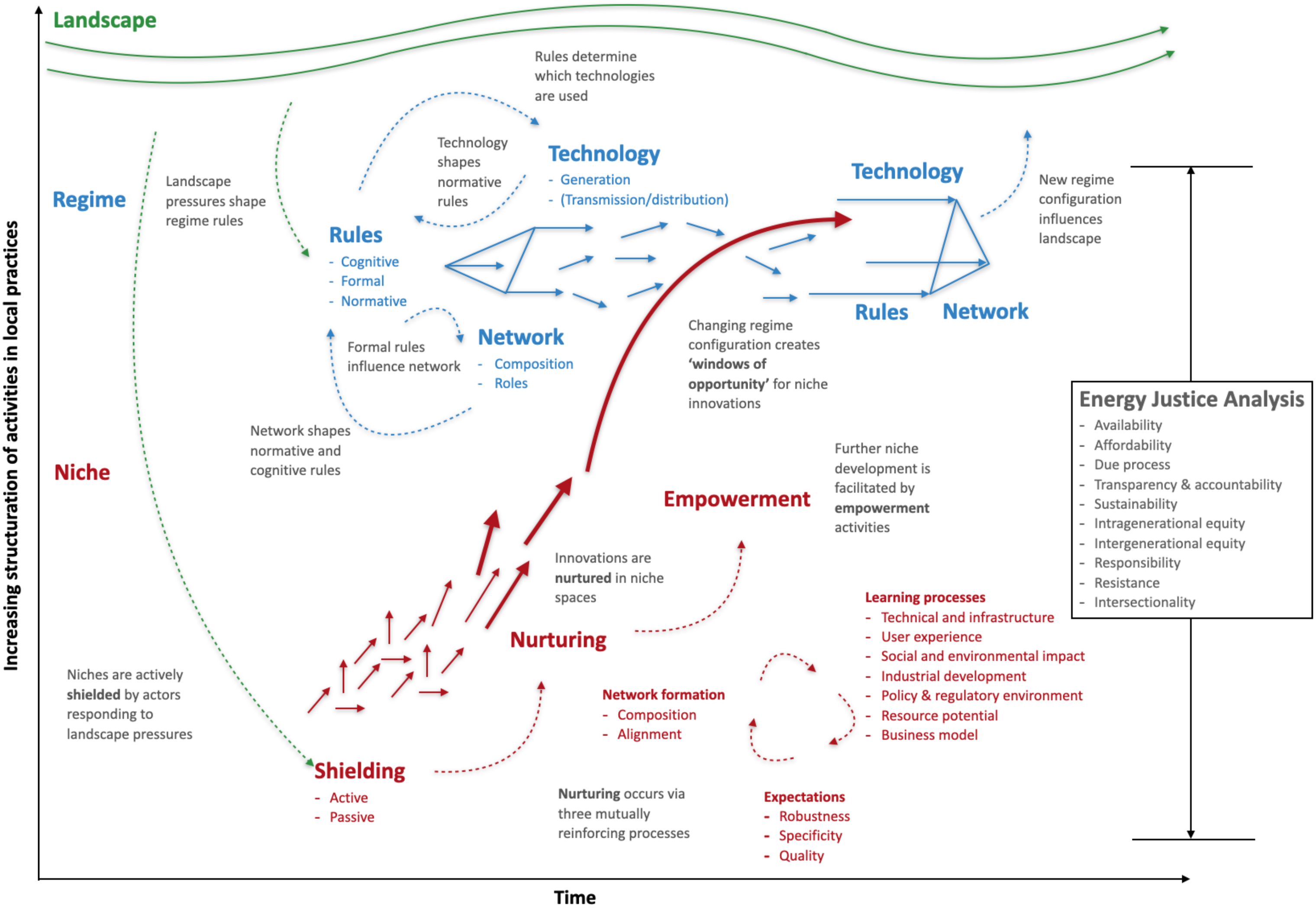


Figure 3.1: Integrated Multi-Level Perspective and Strategic Niche Management and Energy Justice framework (Source: author, adapted from Frank Geels, 2002).

The transition period is split into several periods that are distinct with respect to niche development. The analysis progresses in chronological order, for each period discussing developments at the landscape, regime, and niche levels - Turnheim and Frank Geels, 2019 provide an exemplary example of such a analytical structure in their study of French trams. The division of the study period in this research is discussed below in Section 3.2.2.

An important preliminary step is to clearly define what these levels will mean in this study. Starting with the niche, this study is interested in the potential of biomass for electricity generation due to the social and environmental benefits it can have through the reduction of net emissions, increase in fuel security, creation of jobs, and stimulation of development in marginalised communities (Sansaniwal, Rosen, and Tyagi, 2017). Gasification and direct-combustion are the two main pathways for generating electricity from biomass. This study focuses on the gasification route due to its higher efficiencies and lower emissions (Deshmukh et al., 2013). The niche in this study is therefore defined as **power producing biomass gasification plants**. It is worthwhile to note that the gasification conversion method itself has a long history with coal feedstocks, and now is widely used in the coal industry for chemical production (Fischer-Tropsch process, ammonia, methanol, hydrogen), heat, power and combined heat and power (CHP).

The regime that directly encapsulates the niche is the electricity sector. Three functional subs-sectors are contained within this regime: generation, transmission, and distribution. Developments in the transmission and distribution sub-sectors can influence the niche by expanding electricity supply infrastructure to remote regions where much of the biomass potential is located. The generation sub-sector is comprised of other niche technologies (geothermal, solar and wind), in addition to the existing sources of electricity (coal, oil, gas and (large-scale) hydro - well established in Indonesia). The regime is therefore defined as the **electricity supply business**. The link between regime and niche is shown in Figure 3.2. The biomass gasification niche is also related to, or influenced by other regimes: the agricultural sector deals with the development of the agricultural industries that create the feedstocks for biomass gasification, and the financial sector determines the government budget, sets the electricity tariff, and approves the national energy plan. Developments in this regimes will be researched and included in the analysis.

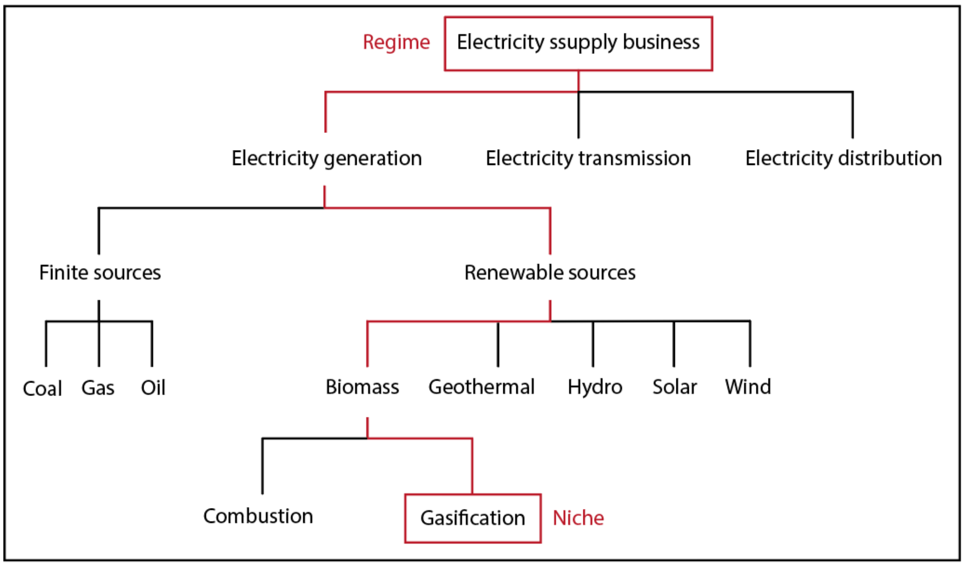


Figure 3.2: Defining the regime and niche levels (Source: author).

Finally, the landscape level is the exogenous environment within which both the regime and niche are nested in. This level will capture slow-moving trends at the national and global scales, in addition to sudden events. Slow-moving trends include: shifts in the national and global economy (employment by sector, commodity and fuel prices, import/export), shifts in demographics, changes in political regime, corruption levels, and climate change. Sudden events refers to violence and conflicts (domestic and international), financial crises and natural disasters.

Defining what each of these conceptual MLP levels means in this specific case study allows the research data to be sorted accordingly. The following sections explain how this data will be connected to the theory and analysed.

3.2.1 Niche Analysis

The niche analysis focuses on the three internal processes discussed in Section 2.2: niche shielding, niche nurturing, and empowerment activities. The nurturing process itself contains three interlinked processes: voicing of expectations, the formation of an actor network and learning processes.

Niche Shielding

Passive shielding can be identified by looking at the location of biomass potential in relation to: the existing electricity grid infrastructure, electrification rates, specific electricity consumption levels by area, and location of agricultural industries. Active shielding can be identified by regulations such as portfolio standards; where a certain share of electricity generation must come from renewable sources, or Feed-in-Tariffs (FiTs), that guarantee a fixed rate of electricity sales, thereby shielding the niche from the selection pressures of the regime.

Niche Nurturing

Voicing and Shaping Expectations: these can be evaluated in terms of robustness, specificity and quality (Hoogma, Weber, and Elzen, 2005).

1. Robustness: as this is a measure of coherence between the the expectations of each actor within the network, first the actor network must be known, and then their expectations determined.
2. Specificity: this should be evident from the voicing of expectations.
3. Quality: this can be evaluated by determining whether or not expectations are supported by experiments or studies.

Learning processes: can either lead to first order, or second order learning. In the first actors learn about the performance of the technology with respect to predefined criteria. First order learning can be divided into seven categories: technical and infrastructure developments, user experience, societal and environmental impact, industrial development, policy and regulatory environment, resource potential, and business models (Hoogma, Weber, and Elzen, 2005; Kamp and Vanheule, 2015). The last two categories are a fairly recent addition to SNM theory (see Kamp and Vanheule, 2015) and are particularly useful for the study of sustainable energy niches like biomass gasification where information about resource potential (i.e. potential biomass feedstocks, quantities, qualities, locations, etc.), and about knowledge of effective business models is limited.

1. Technical and infrastructure developments: this refers to the innovation in gasification technology and relevant sub-units such as flue gas cleaning units, in addition to learning about complementary technology and infrastructure.
2. User experience: this concerns the demand for electricity and difficulties related to operating the biomass power plant. Due to predefined contracts (PPAs for example), the composition of users will be known prior to experimentation.
3. Societal and environmental impact: as the experiments progress, the social and environmental impact of the (current state) technology will become clearer. Key performance indicators could be gaseous emissions, liquid and solid waste streams, energy consumption or land use for feedstocks for example.
4. Industrial development: this involves learning about the production and maintenance network necessary to support the biomass power plant operation.
5. Policy and regulatory environment: this involves learning about relevant legislation at each level of governance, institutional structures and about possibilities for financial support.
6. Resource potential: this involves learning about biomass potential and analysis.
7. Business model: this involves learning about which business models can facilitate facilitate niche development.

The societal and environmental impact learning process is omitted from the framework as these points are covered in the energy justice analysis described below. Societal impact is captured by intragenerational equity, intergenerational equity, and intersectionality, while the environmental impact is captured by the responsibility principle.

Second order learning occurs when actors learn about the norms and values associated with the implementation of the technology in the real world. Second order learning facilitates changes in the cognitive frames that guide niche development and can therefore contribute to niche development more than first order learning (Frank W. Geels and Schot, 2007). Second order learning can be divided into three categories:

1. Problem framing shift: reframing a problem through consideration of alternative frames from other actors.
2. Problem solving and priorities shift: searching for new solutions or methods to solve the problem.
3. Joint learning shift: sharing or adopting problem definitions from other actors.

Science and technology indicators are widely used to show trends in research and development. Publications and patents are the two main indicators used: publications measure the level of research activities, whereas patents measure knowledge-based innovation and commercialisation (A. F. Kirkels and G. P. Verbong, 2011). Caution must be taken when using these indicators since the volume of patents and published articles is much greater today than in 1980 - as the general rate of patenting and publishing has not remained constant the datasets collected do not necessarily translate to a change of interest in the field.

Network Formation: throughout the development of the niche the network will change in size and composition. Actors within the network each have their own perception on the technology which guide their activities. The level of coherence between actors is termed 'network alignment' and is argued to be an important factor in the development of new innovations (R.P.J.M. Raven, 2005). The network analysis for this project will be divided into the network composition and dynamics, and the network alignment.

1. Composition: this involves the identification of actors and their role within the network throughout the time period.
2. Alignment: once the actors have been identified and their expectations understood, network alignment can be evaluated by looking at the coherence between expectations and the interactions between the stakeholders.

Niche Empowerment

Successful shielding and nurturing processes result in niche empowerment; where the niche either becomes competitive within a relatively unchanged selection environment, or actually changes the selection environment. The entrance of the niche into the regime is identifiable through data on electricity generation available from the International Energy Agency and the Indonesian Ministry of Energy and Mineral Resources. The nature of the empowerment can be determined by looking at the selection environment of the regime, and whether there has been any shift in the rules that govern the electricity supply business. The analysis of regime developments is discussed in the following section.

3.2.2 Regime Analysis

The indicators for analysing socio-technical regimes vary slightly across literature depending on the nature of the regime. The electricity sector has been the focal point of several multi-perspective transition case studies (G. Verbong and F. Geels, 2007; G. Verbong and F. Geels, 2010; Geert Verbong and Loorbach, 2012). The electricity regime in these studies have been divided into three sections:

1. Material and technical elements: the resources required to produce electricity (fossil fuels and renewable energy resources, materials, finances) and the infrastructure for the generation, transmission and distribution of electricity

2. Network of actors and social groups: government ministries, regional and local governments, multi-lateral and bi-lateral donors, NGOs, electricity producers (utility and independent power producers), and electricity consumers (household and industry)
3. Rules that govern the sector
   - Formal: laws, regulations (central government ministries, presidential, regional and local government), incentive structures, governance systems, power systems, protocols, standards, procedures
   - Normative: values, norms, role expectations, authority systems
   - Cognitive: priorities, problem agendas, beliefs, bodies of knowledge (paradigms), search heuristics

Regarding the regime rules - G. Verbong and F. Geels, 2007 have acknowledged the existence of both the normative, and cognitive rules in their description of the theory, however, in their analysis of the Dutch electricity sector no mention is made of either of these rules - only formal rules have been discussed in the case study. Similarly, whilst this research acknowledges the existence of these rules, the analysis will focus on the formal rules governing the regime. **In this research it has been useful to split the formal rules further into those which concern plans and strategy, and those which concern regulations and laws.** Plans for the electricity sector provide insight into the landscape pressures acting on the regime and are not always well reflected in the laws and implementing regulations. Such a division provides a stronger link between the landscape level and the regime level - landscape pressures shape the strategy of regime actors, which in turn shape the laws, policies, and implementing regulations. It is useful to note that the formalised strategies and plans also give some indication of government priorities, and therefore also relates somewhat to the cognitive rules. Nevertheless, in this study strategies and plans will be considered as part of the formal rules governing the regime.

It is typical of transition studies to split the time period into several distinct periods. The full studied time period is typically split into several periods that exhibit distinct characteristics in terms in terms of landscape factors, or niche development (G. Verbong and F. Geels, 2007; Frank W Geels, 2019). These papers do not explicitly mention how the time period was split, or if there were possible alternatives. In most historical MLP case studies these time periods are also fairly even in size. In the case of biomass gasification in Indonesia niche activities started back in the late 1970s, started to expand due to both international and domestic interest. Activities stopped almost entirely in the late 1990's due to stabilising global oil prices and the political turbulence that erupted in Indonesia following the Asian financial crisis. Formal energy sector planning and governance stabilised to some extent in 2006 with the introduction of Indonesia's energy management blueprint. In the following years niche activity accelerated, with significant developments occurring around 2012 following the introduction of a Feed-in-Tariff. Several changes to the regulatory environment were later made in 2017. The study time period of 1980 - 2020 is split into three periods - 1980 - 2005 *External Shielding*, 2006 - 2016 *Improving Regulatory Environment*, and 2017 - 2020 *Increasing Niche Momentum.* Unlike the examples found in literature, this case study does not lend itself to equally sized time period. The distinct time periods chosen are 26 years, 11 years, and 4 years. An alternative could have been to include one period between the late 1990's and 2012 but as there were so few niche projects in this time period it was decided to instead form just three periods - the second extending back to the significant moment of formalised energy sector planning as niche activities commenced again around this time. The division into these time periods aids in the structuring of the data, however, no explicit comparisons are made between periods and so the difference in periods is not expected to be a problem.

3.2.3 Landscape Analysis

The landscape level captures all developments on a larger scale than the regime and niche levels. The landscape analysis aims to describe developments that to some extent influence the development of the niche. The extent to which landscape developments influence niche development will vary, and can be direct, or indirect. For example, although the oil crises of the 1970s did not stimulate interest in biomass gasification within the Indonesian regime actors, however it did stimulate interest in the international community, who in turn invested in experiments in Indonesia, in addition to other developing countries. On the other hand, the growing pressure in the international community to combat climate change has resulted in changes to the electricity regime through renewable energy target and regulations. Some landscape factors like corruption and violence impact niche development in a more discrete manner through inefficient use of human and financial resources, in addition to problems implementing local projects. These factors will be discussed and supporting using relevant literature from global experiences of such factors, and where possible, supported with data specific to the Indonesian case - either through publicly available data or through interview responses.

3.2.4 Energy Justice

Efforts have been made recently to discuss energy justice concepts and integrate them in existing transition frameworks (Sovacool, M. Burke, et al., 2017; Jenkins, Sovacool, and McCauley, 2018). Energy justice frameworks can act as a lens through which projects at the niche level, dimensions at the level regime, and political framing at the landscape level, can be assessed (Jenkins, Sovacool, and McCauley, 2018).

The historical nature of this project, in which a 40 year transition period is considered, has several implications for the energy justice analysis. First, to limit the scope of the energy justice analysis, it is necessary to discuss which levels of the MLP would add significant value to the case study. As the focus of this study is on the development of biomass gasification, analysis on the niche level is essential. Analysis at the regime level adds significant practical value and academic value to the study - practically, it puts the energy justice analysis of the niche in the context of the incumbent regime, while academically it provides a strong link between the MLP and Energy Justice frameworks in which 'windows of opportunity' for niche innovations are identified. To limit the scope, an individual energy justice analysis will not be performed on the landscape level. Instead, landscape pressures that relate to justice will be discussed in the analysis of landscape factors, and the interaction of energy justice between the three levels will be discussed in the conclusion of each transition period.

The application of energy justice to such a historical study has two further implications for the analysis. Firstly, due to the large scope, the depth of analysis will be less in comparison with studies that either consider a shorter time period or have smaller scopes. A second implication is that the availability of information can be limited. This challenge is also very true for case studies in countries like Indonesia, where information on energy projects, particularly biomass gasification projects, is very limited. **The availability of data determined which energy justice principles can be analysed for each transition period, and the level of detail that can be achieved in the analysis** - Table 3.1 provides an overview of principles covered on the regime and niche levels, for each time period.

At the niche level not all principles from Sovacool's framework are considered - either due to data availability, or the lack of added analytical value. In comparison with large-scale energy projects, small-scale projects have much fewer regulations to abide by - for example environmental impact assessments are not required for projects smaller than 10 MW. Nonetheless, no examples were found of biomass gasification projects violating *due process*. Likewise, no examples were found of *resistance* to injustices caused by biomass gasification projects. These principles, *due process* (3) and *resistance* (9), are therefore omitted from the niche energy justice analysis. **Furthermore, for this case of biomass gasification in Indonesia not all of the energy justice principles will add significant value to the transition analysis** - looking at their definitions in Table 2.1, one can understand that due to the nature of the biomass gasification process, projects inherently contribute to both *sustainability* (5) and *intergenerational equity* (7). The lack of variation in these principles between projects makes commenting on these principles for each project, in each transition period, unnecessary.

At the niche level, individual projects are assessed with respect to the remaining six principles of Sovacool's framework. Biomass gasification project information regarding: the electricity users, cost of electricity generation, quantity of electricity supply, the previous electricity source or lighting source (e.g. kerosene lamps), source of biomass (e.g. tree plantation or agro-industry waste), emission levels, and treatment of waste streams, can all be used to assess the impact on the energy justice principles.

For an example of how niche projects are assessed with respect to the energy justice principles consider the first two principles: *availability* states that all people have a right to sufficient quantity and quality energy resources to meet their basic needs. Analysis from the International Energy Agency and the United Nations Secretary-General's Advisory Group on Energy and Climate Change (AGECC) states that **50 - 100 kWh/person/year is required for basic human needs** of lighting, health, education, communication, and community services (AGECC, 2010). Figure 3.3 shows the different levels of electricity supply necessary for basic human needs, productive uses, and modern society.

The second principle is *affordability*; which states that all people, including the poor should pay no more than 10% of their income for energy services. With information regarding the cost of electricity supply and quantity of electricity supply, it is possible to assess the impact of biomass gasification projects on the first two principles of energy justice.

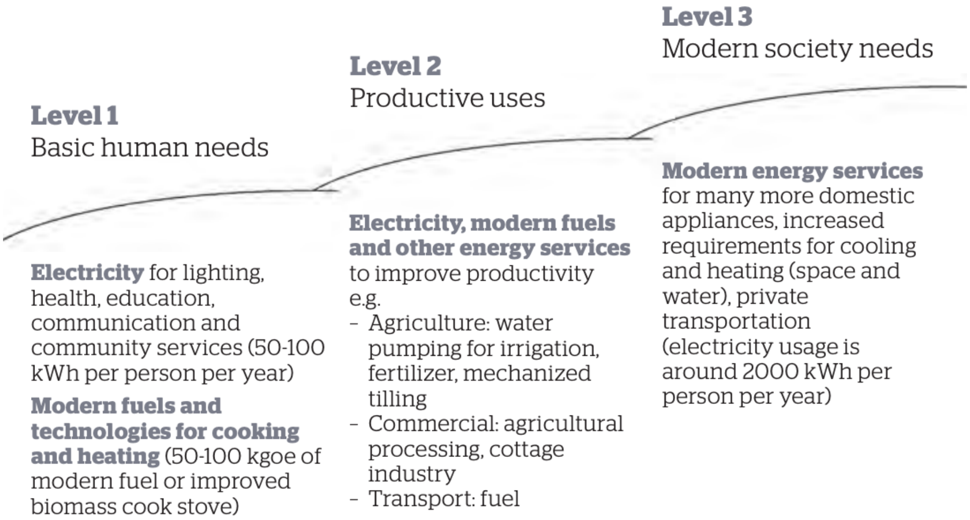


Figure 3.3: Electricity consumption levels (Source: IEA, 2020a; AGECC, 2010).

At the regime level, covering all ten principles of Sovacool's framework is very challenging considering the large scope of the thesis and also the limited availability of data. Regarding data availability, publicly accessible information regarding energy production, consumption, proved reserves, and emission levels will facilitate the analysis of *availability*, *affordability*, *sustainability*, *intragenerational equity*, and *intergenerational equity*. Analysis of *due process* relies on published research that has collected primary data, and from news article reports on *due process* violations of electricity projects. The *due process* analysis greatly benefits from Anna Fünfgeld's ethnographic research on coal mining in Indonesia. The *transparency and accountability* principle look at the access to high quality information about the electricity sector and impacts - this is deducible from looking at the publicly available information published by the government, and also from specific case studies on energy projects. To analyse *responsibility* this research will draw on research which details the actual environmental impact of certain energy projects, and also connect the dots between deforestation and the location of energy projects - this is most relevant for coal-fired power as these require large coal mining permits. This investigative work also benefits the analysis of how the *responsibility* principle intersects with the environmental justice and the justice for non-human life - comparing spatial deforestation data, to the location of coal mining permits, and spatial data for biodiversity and location of endemic species, gives some insight into the real impact of these activities. Analysis of the penultimate principle, *resistance*, draws on research papers, news articles, and websites for resistance movements such as the anti-coal movement. The final principle, *intersectionality*, is the broadest as it should encapsulate how energy projects impacts other forms of justice, such as gender, health, environmental, socio-economic. The analysis presented for this principle is dependent on the availability of data and is constrained by the research time period, and also the ability of the researcher to identify the intersections between justice elements. For example, the impact of Indonesia's coal pipeline on human health was discussed using the results from the NewClimate Institute's AIRPOLIM-ES tool which combines emissions data with a concentration-response function to estimate the prevalence of disease and resulting morbidity that is caused by coal-fired power plants in Indonesia (New Climate Institute, 2020).

To summarise, the energy justice analysis - for the regime level considers all principles, at the niche level *due process*, *sustainability*, *intergenerational equity*, and *resistance* are omitted from the niche analysis (Table 3.1). Analysis of *transparency and accountability* for the niche level was omitted in the first period due to the lack of available data.

Table 3.1: Energy Justice Analysis

Principle	Regime			Niche		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
1 Availability	x	x	x	x	x	x
2 Affordability	x	x	x	x	x	x
3 Due Process	x	x	x			
4 Transparency and accountability	x	x	x		x	x
5 Sustainability	x	x	x			
6 Intragenerational equity	x	x	x	x	x	x
7 Intergenerational equity	x	x	x			
8 Responsibility	x	x	x	x	x	x
9 Resistance	x	x	x			
10 Intersectionality	x	x	x	x	x	x

3.3 Data Collection

3.3.1 Desk Research

Google was used to search for relevant landscape, regime, and niche developments, using a combination of keywords and operators (AND/OR) to narrow down the results. These searches were also made in Indonesian, benefiting from Google's automatic translation of results on the search page and on websites. Documents that were only available in Indonesian were translated by copying text piece by piece into Google Translate. Data was collected from a wide variety of sources including: articles, reports, websites, data banks (e.g. World Bank, 2020b; BP, 2020), new articles, and social media posts. Over the course of ten months several hundred such documents were reviewed. This extensive desk research spanned almost the entire duration of the project, running side-by-side with the analysis and the writing of the report. The preliminary research, conducted during the development of the thesis proposal, identified several biomass gasification projects throughout the study period. Due to the undeveloped and uncoordinated nature of biomass gasification development in Indonesia, data collection for the niche level was particularly challenging - this was evident from the early stages of the project. Before progressing further with the niche level, research on the regime level was performed in order to build a picture of how Indonesia's electricity sector has developed over time. This thorough regime research was complimented by simultaneous research on the landscape level, which provided value insights into the context in which the electricity regime was developing. Once a clear overview of developments at the regime and landscape levels had been obtained, a more intensive round of research on the niche level commenced.

Due to the severe lack of data on niche projects, desk research alone was not sufficient to build an understanding of the actor networks, the learning processes, and actor expectations. The desk research was therefore complimented by semi-structured interviews and direct document sharing with niche actors.

3.3.2 Interviews

Interviews were used to uncover insights above and beyond what would have been possible through desk research alone. This is particularly true for the analysis at the niche level; where information necessary for both the SNM and energy justice chapters was not available. A semi-structured interview design was chosen to ensure that all previously identified knowledge gaps were investigated, while also providing sufficient flexibility for exploring related topics (Holland and Edwards, 2013).

The interview questions were based on the MLP, SNM, and Energy Justice frameworks - these are shown in Appendix B. The standard questions included actor expectations, project experiences, project outcomes, the nature of stakeholder participation, the interaction between actors in the network, and external factors. A different interview script was created for plant operators in order to capitalise on the opportunity to gain deeper insights into plant performances and project experiences. The standard questions were open-ended to allow the interviewee to answer freely. The questions relating to the most impactful research topics were addressed first to ensure sufficient information was collected on them before moving on to less impactful questions.

A diverse range of interviewees was sought in order to obtain divergent insights on the biomass gasification niche. Interviewees were selected based on their involvement with niche projects. Identifying and contacting relevant actors required a significant amount of investigation. With the exception of one interviewee, all interviewees were contacted directly by the author through various channels: LinkedIn, WhatsApp, and Email. The other interviewee contact was supplied through the TU Delft - ITB collaborative project. A snowball sampling method, in which interviewees were asked to suggest names of relevant actors, was utilised in order to increase the number of relevant interviewees, however, this only led to one additional interviewee. The details for each interview are shown below in Table 3.2.

Eight of the ten interviewees participated in an online video interview on Zoom. The remaining two participated by responding the interview questions in writing. Of the eight video interviews, seven were conducted by the author, while one was delegated. The failure to arrange interview assistance from ITB did not impact the conduction of interviews - the one interview that had to be conducted in Indonesian was delegated to a former colleague of the author's, based in Indonesia.

Seven of the eight video interviews were transcribed by the author, while the delegated interview was transcribed by the interviewer and translated into English. The interviews were transcribed verbatim and imported to ATLAS.ti - a computer-aided qualitative data analysis software (version 8.4.4, 2019, ATLAS.ti Scientific Software Development GmbH). A coding scheme was developed using the terms outlined in the Methodology (Chapter 3). Coded segments contain a quotation, and a code. The interview transcripts were analysed by searching for coded segments. The use of the coding software did not impact the analysis greatly as the total number of interviewees was small and were analysed on a rolling basis.

Table 3.2: Interview Details

No.	Actor Type	Interview Type	Date of Interview
1	Domestic project developer	Video interview	28-10-2020
2	Researcher - biomass gasification	Written interview	13-11-2020
3	Researcher - biomass gasification	Written interview	14-11-2020
4	Researcher - biomass gasification Industrial user	Video interview	17-11-2020
5	International project facilitator	Video interview	15-12-2020
6	Operator	Delegated video interview	17-12-2020
7	Researcher - forestry	Video interview	17-12-2020
8	Government official	Video interview	24-12-2020
9	Independent consultant Researcher - biomass gasification	Video interview	04-01-2021
10	Manufacturer	Video interview	08-01-2021

4 Background Information

4.1 Biomass Gasification

4.1.1 Overview

Electricity generation from biomass starts with the collection of raw biomass. In the case of energy crops (not waste products) this will also include harvesting. The next stage is the pre-treatment, where harmful material (stones and adherent soil) are removed, the particle size is reduced, and the moisture content is reduced, from 30 - 60 wt% 'as received', to less than 20% (De Jong and Ommen, 2014). Lignocellulosic biomass and residues can also be torrefied before the gasification step to improve handling, storage, and to increase the energy density of the fuel. In the gasifier the solid pre-treated or torrefied biomass is then thermochemically converted using a gaseous agent (air, steam, carbon dioxide, or oxygen) to produce a combustible gas containing hydrogen, carbon monoxide, carbon dioxide, methane and water vapour (De Jong and Ommen, 2014). The produced gas can be used for: heat generation, electricity generation, combined heat and power, or for producing biofuels and chemicals such as methanol. The general block flow diagram of the biomass gasification process is shown in Figure 4.1. The performance of the system is dependent on the functioning of these internal processes and pieces of equipment.

The biomass gasification facility has an upstream, and downstream supply chain. The upstream supply chain concerns: the feedstock(s), supplier(s), quantities, quality, prices, water, equipment, and finances. Additional feedstocks may be investigated for co-firing or backup purposes. The downstream supply chain concerns: energy supply, quantities, quality, reliability, and customers. The demand of, and price paid by the customer determines several important characteristics of the process; such as the minimum operating time required to meet the demand. The downstream supply chain also considers the treatment of process waste products and waste valorization (e.g. sale of biochar as fertiliser).

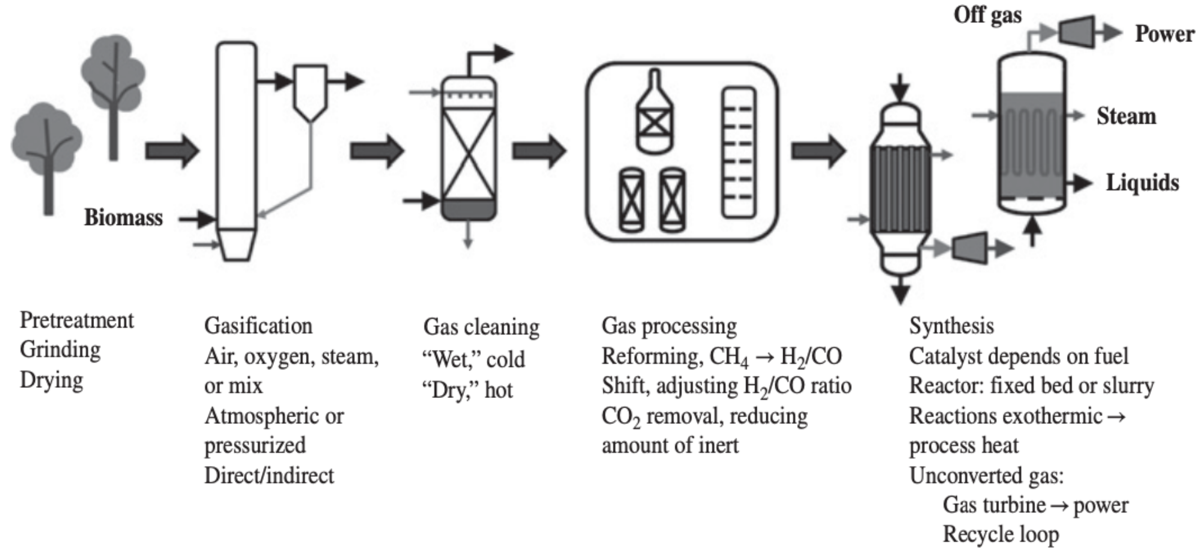


Figure 4.1: Overview of typical biomass gasification facility (Source: De Jong and Ommen, 2014, adapted from Olofsson, Nordin, and Söderlind, 2005).

4.1.2 Feedstock

The choice of feedstock depends on availability, desired quality of product gas, and the type of gasifier used. Feedstock availability refers not only to physical presence but also the social and environmental acceptability, and feasibility in terms of economics and regulations. These factors are often dynamic and so can cause challenges for potential and existing projects.

The physical and thermochemical properties of the feedstock have implications for the process design (Table 4.1). The physical properties influence the choice of gasifier and determine the requirements for pretreatment units. The thermochemical properties directly affects the composition of the product gas and so determines the requirements for gas cleaning units, and the performance in downstream operation like power generation.

Table 4.1 provides some indication into the complexity of the biomass gasification process - many physical and thermochemical properties of the feedstock influence the overall performance of the process. As the process is sensitive to small changes in these properties, a key challenge for biomass gasification projects is ensuring a continuous supply of homogeneous feedstock.

Table 4.1: Impact of feedstock physical and thermochemical properties on gasification process (Source: IEA Bioenergy Task 33, 2014, p. 2).

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.
Chemical	
Cellulose, hemicellulose and lignin content	- Reactivity of fuel.
Ultimate analysis - C, H, O content	- Heating value of fuel.
Ultimate analysis - N content	- Fate of fuel-bound N during gasification: mainly transformed into NH 3 and HCN - design of gas cleaning section. - Emissions.
Ultimate analysis - S content	- Fate of fuel-bound S during gasification: mainly transformed into H2S and COS - design of gas cleaning section. - Interaction with alkali metals: emissions, deposits, corrosion. - Deactivation of downstream catalysts.
Ultimate analysis - Cl content	- Decrease of softening temperature of ash. - Enhancement mobility of K (deposition and agglomeration).
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.
Ash composition - 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.
Ash composition - Mg, P, Ca content	- Increase of ash melting temperature. - Ash disposal applications.
Ash composition - Heavy metals	- Emissions. - Ash disposal costs, ash applications.

4.1.3 Pretreatment

The gasification process requires small particles in order to achieve sufficient particulate residence times and fuel conversion due to higher available specific surface area for mass and heat transfer. Biomass feedstocks are typically available in sizes that are far too large to achieve sufficient gasifier performances and so various particle-size reduction units are necessary prior to the gasifier. Furthermore, biomass feedstocks are typically available with high moisture contents of 30 - 60 wt% (De Jong and Ommen, 2014). High moisture content is not desirable as heat is used to vaporise the water - the effective heating value of the fuel is therefore lower. Moisture reduction and particle-size reduction are therefore both crucial to the overall gasification plant performance. Many of the problems experienced in practice are due to poor pretreatment of feedstock.

Due to the fibrous nature of biomass crushing forces only break down a small fraction of the feed - the rest is simply compressed or deformed and stretched. Shearing, ripping and cutting forces are therefore required for biomass size reduction. Chunking is used to reduce the size of large biomass pieces like trees, down to 50 - 250 mm. Chipping and shredding are used to further reduce the particle size to 25 - 50 mm, which is sufficient for updraft and downdraft gasifiers. Various milling units can be used to obtain the finest biomass particles.

The extent to which drying is needed depends on the feedstock and the gasifier. Drying can be natural, mechanical, or thermal, and carried out in either a batch or continuous mode. The simplest, and cheapest method is natural drying in the open air. The final moisture content depends on the initial moisture content, the climate, and the drying time. Mechanical drying processes use compression forces to dewater the feedstock. The most common types of mechanical dryers are screw presses, mechanical presses, and roller presses. These units consume large amounts of energy and typically have high maintenance requirements. Thermal drying is the most energy-intense of the three processes. This drying can be either direct or in-direct: in the first, biomass is directly contacted with the drying medium (hot air, steam, or hot flue gas), while for the latter, heat is transferred via conduction through a casing. The selection of the dryer depends on the physical characteristics of the feedstock, quantities, and required moisture reduction.

Biomass feedstocks can also be compacted by briquetting and pelletizing. The increased apparent density of the biomass increases the energy density and uniformity of the feedstock; which improves handling (and safety through reduction of loose fine particles) for storage and transportation.

4.1.4 Gasification

Gasification is the thermochemical process by which liquid or solid fuel is converted into a gas using a gaseous agent (air/steam/oxygen) at high temperature. When air is used as the agent the combustible product gas contains H_2, CO, CO_2, and CH_4, along with H_2O, N_2, and various other heavier hydrocarbons in small amounts. The gasification process is characterised by three successive subprocesses: drying, pyrolysis, and gasification. In the pyrolysis stage, the main organic content of the biomass is converted into char, permanent gases, and longer chain hydrocarbons referred to as tars. In the subsequent gasification stage tars and char particles react with H_2O and CO_2 at higher temperatures (700 - 1500 °C) to produce more permanent gases.

Several reactor types are suitable for biomass gasification and can be classified by the transportation of fluids and solids: quasi-non or self-moving feedstock, mechanical-moved feedstock, fluidically-moved feedstock, and special reactors (Warnecke, 2000). The two main types of gasifiers used for biomass are fixed bed (quasi-non or self-moving feedstock), and fluidized-bed (fluidically-moved feedstock). Fixed bed reactors can either be updraft (counter-current flow of feedstock and gaseous agent), or downdraft (co-current). The main type of fluidized-bed reactor for biomass gasification utilises a circulating bed (CFB).

In downdraft gasifiers the fuel flows from the top of the reactor. The first reaction zone is the drying zone, followed by the pyrolysis zone, the combustion zone, and the gasification zone. In this configuration the product gas is relatively clean as it leaves at the bottom of the reactor, below the combustion zone where the tars are cracked at high temperature. This configuration is the most common for small-scale applications due to its simplicity and reliability. In updraft gasifiers, biomass is dried by rising hot producer gas. The char produced from the pyrolysis zone flows downwards, while the tars and permanent gases flow upwards. Only a fraction of the tars produced in the pyrolysis zone condense on the biomass particles in the drying zone. The high hydrocarbon content of the product gas from updraft gasifiers results in a higher heating value in comparison to other configurations, however the tar content is also much higher and requires extensive cleaning prior to use in power generating equipment. Finally, in CFBs the gasifying agent (or fluidizing medium) is blown from the bottom of the reactor at velocities sufficient to lift the bed of inert of solid particles. The bed material is used to enhance the transfer of mass and heat. The turbulence of the bed created by the gasifying medium creates an even temperature distribution in the reactor (700 - 900 °C). The implication of this even distribution is that there are no distinct reaction zones in the reactor. The high velocity of the fluidizing medium results in solids being entrained in the product gas. A cyclone is used to separate these solids from the product gas and recycle them to the bottom of the gasifier. The cyclone does not effectively separate dust and so further gas cleaning is required.

The selection of a gasifier type depends largely on four factors: (1) scale of process, (2) feedstock characteristics (particle size and composition), (3) sensitivity to ash, and (4) tar generation. Of these factors, scale is the primary criterion (De Jong and Ommen, 2014). The suitable scales for each reactor type is shown below in Table 4.2. Small-scale applications, for example for rural electrification, require reactors with low capital cost that are also relatively simple to control and maintain. Feedstock flexibility refers to the ability of the gasifier to withstand fluctuations in the size and composition of the feedstock. As feedstock pretreatment (size reduction and drying) are fairly energy-intense processes, it is beneficial minimise the requirements of these processes. Furthermore, in cases where there is some uncertainty over the long-term supply of feedstock it would be beneficial to choose a gasifier design that can handle changes in feedstock composition. CFBs are relatively sensitive to the presence of alkali metals as they cause bed agglomeration which can significantly reduce the efficiency of the process. CFBs would be suitable for wood feedstocks, which have low ash content and is comprised largely of calcium and silica, however, they would be unsuitable for use with agriculture residues as these have much higher ash content and can have significant alkali metal content. Finally, **excessive tar production can be a serious issue for units downstream of the gasifier such as gas engines**. Due to the countercurrent flow in updraft gasifiers, and the lower temperatures in CFB gasifiers, tar generation is greater than in downdraft gasifiers. Sufficient gas cleaning processes are necessary to protect downstream equipment from fouling.

Table 4.2: Comparison of gasifier types (Source: Pirard, Bär, Cahyat, et al., 2017, p. 6).

	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
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

4.1.5 Gas Cleaning

The downstream units that utilise the product gas impose different restrictions on the acceptable levels of contaminants which include: particulate matter, tars, sulphur species, chlorine species, alkali and trace elements, and nitrogen compounds. These contaminants are the result of the thermochemical processing in the gasifier and so depend not only on the composition of the feedstock, but also on the choice of pre-treatment, gasifier, and operating conditions. The concentration limits of various contaminants is shown below in Table 4.3 for the case of internal combustion engines, and gas engines.

Particulate matter in the raw product gas typically ranges between 0.1 and 100 μm. The performance of several common particulate matter filters are shown below.

Table 4.3: Product gas contaminant limits for power production (Source: De Jong and Ommen, 2014, p. 338).

	Application	
Contaminant	IC engine	Gas turbine
Particulate matter (soot, dust, char, ash)	<50 mg.mn^{-3} (PM10)	<30 mg.mn^{-3} (PM10)
Tars - Condensables - Inhibitory species (class 2 heteroatoms, benzene, toluene, xylenes)	<100 mg.mn^{-3}	
Sulfur species (H_2S, COS)		<20 ppm
Nitrogen species (NH_3, HCN)		<50 ppm
Alkali compounds		<24 ppb
Halides (mostly HCl)		1 ppm

Tars can either be reduced *in situ* through careful selection of operating conditions, gasifier design, and use of catalysts and additives. Tars can also be reduced in units downstream of the gasifier. Both methods can also be combined to achieve sufficient tar reduction required for downstream equipment. In terms of operating conditions, the choice of gasifying agent, temperature, stoichiometric oxygen ratio, and residence play key roles. High temperatures reduce tar concentrations as they breakdown at around 1200 °C. High stoichiometric oxygen ratio facilitates tar decomposition but also increases the CO_2 content in the product gas which lowers the heating value. The use of additives such as dolomites, magnesites, limestones, olivines, and Ni-based catalysts, have been shown to vastly reduce downstream gas cleaning needs.

As with tars, sulphur compounds can either be reduced in the gasifier, or in units downstream of the gasifier. Limestone and dolomite can also be used to capture sulphur species in the gasifier. Wet or dry desulfurization units can be used, however, the overall plant efficiency benefits from dry processes as they can be performed at much higher temperatures. Oxides of zinc, copper, manganese, and iron, have been used for dry desulfurization; each with their own benefits and limitations. Metal additives (e.g. Ti, Al, etc.) and promoters (e.g. Co, Ni, etc.) can be added to sorbents to increase their adsorption capacity and lower regeneration energy requirements.

For nitrogen compounds (mainly ammonia), either wet or dry scrubbing may be applied. Dry scrubbing is generally preferred as it can be performed at higher temperatures, and avoids creating a liquid waste stream that would need to be treated. The sorbents used for the removal of tar and sulphur species also effectively capture ammonia. These sorbents can also be used to capture chlorine species. Finally, for alkali species and trace metals, *in situ* removal is preferred, and is done using clay minerals.

4.1.6 Application and Implementation

Experimentation with biomass gasification technology starts with resource availability and consideration of suitable applications - which is based on the expectations of niche actors. The type and scale of the gasifier mainly depends on the choice of biomass and application (A. Kirkels and de Boer, 2009).

Table 4.4: Applications of biomass gasification and the interventions required for effective deployment (Source: Ghosh, D Sagar, and Kishore, 2006, p. 1581).

Application	Objective	Interventions
Informal enterprises 10 - 30 kWe	Provide process hear to substitute liquid fuels or inefficient biomass combustion	Minor technology/product development; technology standardization and/or open technology; involve mid-to-large manufacturers and small-scale manufacturers; promote entrepreneurs as ESCOs; train financiers; provide favorable financing for capital costs and working capital
Small and medium enterprises 30 - 200 kWe	Provide process hear to substitute liquid fuels or inefficient biomass combustion Provide power to replace grid power or liquid-fuel-based power	Minor technology/product development; involve mid-to-large manufacturers; train financiers; help develop biomass markets Technology/product development; involve mid-to-large manufacturers; train financiers; help develop biomass markets
Captive power 100 - 500 kWe	Utilise excess/waste biomass to generate electricity to replace grid power	Technology/product development; involve large manufacturers; train financiers
Rural 10 - 50 kWe	Provide modern energy services to remote villages for social and human development	Minor technology/product development; product standardization and/or open technology; involve mid-to-large manufacturers and small-scale manufacturers; promote NGOs and other organizations as ESCOs; provide subsidies for capital costs; favorable financing for working capital
Rural 100 - 500 kWe	Provide modern energy services to remote villages for social and human development; replace/augment grid power	Technology/product development; involve large-scale manufacturers; promote NGOs and other organizations as ESCOs; provide subsidies for capital costs; favorable financing for working capital

4.2 Overview of Actor Types

This section aims to give an overview of the actors involved in the development of biomass gasification in Indonesia. The value chain of biomass gasification projects, from feedstock planting to final use such as power generation, involves a wide variety of stakeholders, each with distinct roles, capacities, and expectations. Feedstocks are either wastes from agro-industries (e.g. palm kernel shells and rice husks), or woody biomass from forestry residue or from tree plantations - each feedstock has a different value chain and involves different actors. For example, for the typical case of a biomass gasification plant that wishes to supply electricity to a rural community - it may buy the feedstock from an agro-business like a palm oil plantation or a tree plantation owner, or they may opt to involve the local community in the collection of wood residues or facilitate community-grown biomass crops. The next part of the process - the biomass gasification plant - involves a number of actors to develop the proposal; provide capital; design the plant; manufacture the process equipment; construct, build, operate (and provide the necessary training), maintain and manage the power plant; purchase and distribute the electricity (PLN); and finally to coordinate with the local community, NGOs, and local government. The central government also plays a key role in forming the regulatory environment and facilitating projects.

Indonesia has a multi-level governance system, comprised of the central government, provincial authorities, regency authorities, village authorities, and district authorities - Figure A.13 in Appendix A provides an overview of these actors an their roles. While the central government remains responsible for national energy targets and plans, the decentralisation reforms in the early 2000's shifted administrative and regulatory power relating to energy policy and project implementation to the local governments (Markard and Hoffmann, 2016). At the central government level a number of ministries play key roles in the electricity sector - the Ministry of Energy and Mineral Resources (MEMR) formulates energy plans, policies, and regulations; the Ministry of Finance (MoF) is responsible for subsidies and loans (such as Feed-in-Tariffs for renewables); the Ministry of Development Planning (Bappenas) has been involved in the implementation of renewable energy projects; the Ministry of Environment and Forestry (MoEF) issues permits for land acquisitions on forest land; the Ministry of Agriculture (MoA) formulate land-use regulations; and the Ministry of State-Owned Enterprises (MSOE) sets and reviews PLN's performance targets and approves their annual budget. Policies concerning renewables involve several several ministries and are formulated by interministerial working groups. At the local government level renewable energy projects need to obtain licences for the use of land, water, the construction, and power distribution (Kuvarakul et al., 2014) - a process which can involve 10 - 12 agencies for energy, environment, agriculture, etc. (Markard and Hoffmann, 2016).

There are several Indonesian research institutes working on biomass gasification. Firstly, the Government's involvement in research and development activities relating to technology through the Agency for The Assessment and Application of Technology (BPPT). The research and development departments of several government ministries, namely the Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC), MoA, and MoEF, are also involved to varying extents with biomass power generation. Several universities have actively researched biomass gasification; in particular ITB, Universitas Indonesia, Gadjah Mada University, and Udayana university.

5 1980 - 2006: External Niche Shielding

5.1 Landscape 1980 - 2005

The foundations of Indonesia's current institutional structure dates back to President Sukarno's Guided Democracy (1957 - 1965) which relied on state-owned enterprises (SOEs) for the provision of essential goods and services. This institutional structure ensured that the Government retained control of key economic sectors, but also remained **responsible for achieving social justice for its citizens** - one of the five principles of the Pancasila philosophy and Indonesian state identity (Indonesia Investments, 2020b). Liberalisation measures under Suharto's New Order authoritarian regime saw the dismantlement of several SOEs to facilitate private sector investment, however, the energy sector remained fully under the control of the Government (Indonesia Investments, 2020c; Purra, 2011). Under Suharto's New Order regime, state officials created a system of patronage using their access to licences, concessions and funds (Hadiz and Robison, 2013). State actors became increasingly involved in business activities, establishing vast family business conglomerates. Powerful business actors were also able to buy their way into the political arena and support their economic interests. Despite the the fall of Suharto's New Order regime and democratisation during the 'Reformasi' period, the political and economic spheres remained highly connected. The decentralisation reforms of 1999, which transferred extensive autonomy to the regions and away from the central government, led to the further entanglement of politics and business through patronage, self-enrichment, and corruption in the central, provincial, and local governments (Hadiz and Robison, 2013). The relationship between political and business actors has characterised the development of the electricity regime; in particular the heavy reliance on coal-fired power generation and its high degree of stability within the regime.

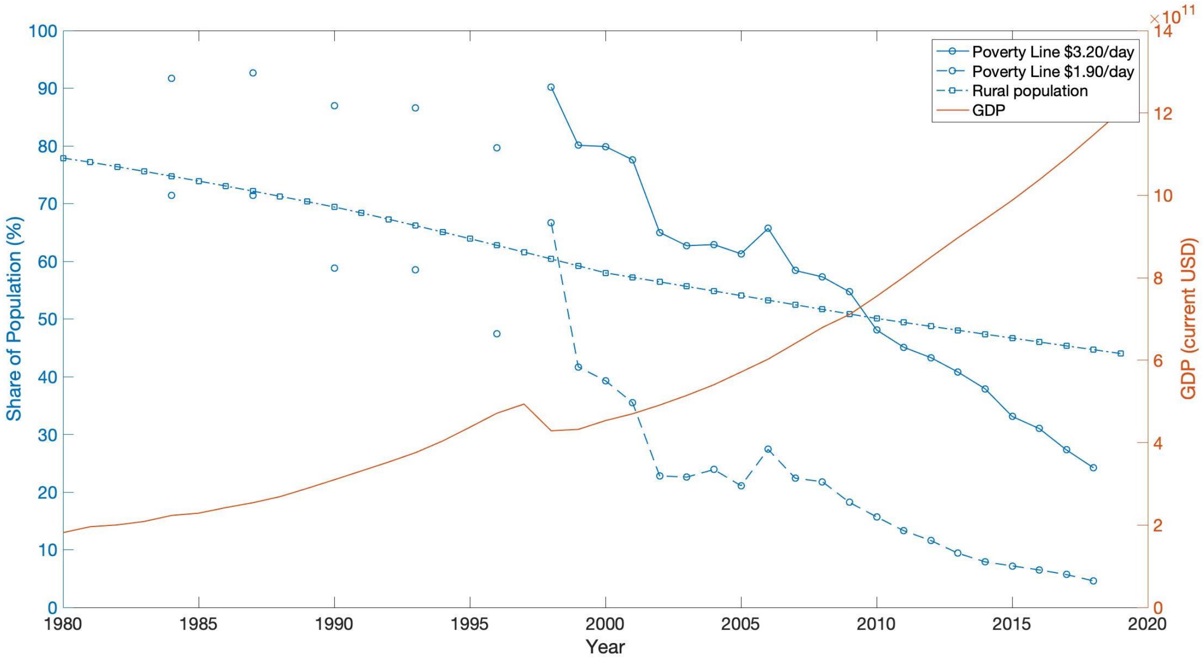


Figure 5.1: GDP, Poverty Headcount, and Rural Population in Indonesia 1980 - 2020 (Source: World Bank, 2020b).

Examining the socio-economic conditions sheds some light on the priorities of regime actors during this period. In 1980 Indonesia was home to 147.5 million people, and the vast majority (78%) lived in rural communities (Figure 5.1). The poverty headcount at this time was over 70% considering a $1.90

poverty line, and over 90% considering a $ 3.20 poverty line (World Bank, 2020b). Per capita electricity consumption was just 46 kWh - to put this in perspective this was almost 100 times lower than per capita electricity consumption in the Netherlands in the same year (Our World in Data, 2020). Figure A.1 shows the evolution of per-capita electricity consumption for several countries across the world between 1985 and 2019.

The 1973 and 1978 oil crises were significant global 'shock' events that characterised development in Indonesia in the 1980s. At this time Indonesia was a member of OPEC and was producing over 1 million barrels of oil per day (BP, 2020). Export revenues from oil soared during these crises and resulted in increases in public expenditure on healthcare, education and infrastructure (Figure 5.2).

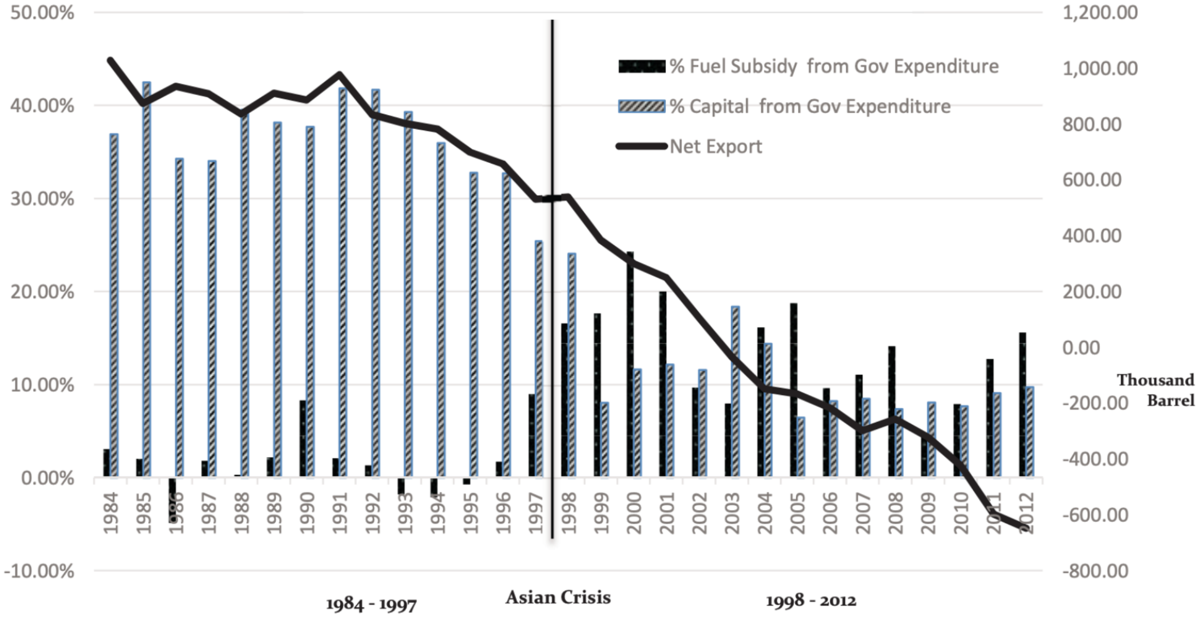


Figure 5.2: Oil subsidies, exports and development expenditure in Indonesia 1984-2012 (Source: Kaneko, Luthfi, and Senevirathne, 2017).

These developments lead to a shift in employment from the agriculture sector to services and industry (Figure A.3), a movement of people from rural communities to industrialising cities (Figure 5.1), rising per-capita energy consumption (Figure A.1), and decreasing poverty levels (Figure 5.1). In contrast, the oil crises seriously threatened energy security in non-oil exporting nations who had become very dependent on oil imports from OPEC countries. This stimulated interest in alternative energy sources like biomass gasification, and led to Western countries funding demonstration projects nationally and internationally in developing countries including Indonesia (Stassen, 1995; Maniatis, 1989; Interviewee 2 - Researcher, 2020).

Trends in oil production, consumption, and subsidies are key landscape factors that began to exert significant pressure on the regime in the late 1990s, and have persisted into the present day. Domestic oil consumption increased in response to abundant production in the 1980s, however, by the early

1990s oil production started to decrease rapidly as mature oil sources were depleted (pwc, 2017) (Figure 5.2). Domestic oil consumption trends are stabilised by commitments to technology, infrastructure, supply chains, and user preferences - for example diesel power plants, automobiles, and kerosene cooking fuel (Figure A.4). Furthermore, domestic oil consumption was subsidised by the Government in order to increase energy access and per capita energy consumption despite the high levels of poverty. The increasing domestic oil consumption caused government expenditure on fuel subsidies to increase from just a few percent, to almost 25% by 2005 (Figure 5.2). Expenditure on the growing oil imports was worsened by increasing international prices (Figure A.6 and Figure A.7). Together these factors put the Government under serious pressure to transition away from oil.

The next shock event at the landscape level was the Asian financial crisis of 1997. Indonesia's GDP growth contracted from 4.6% in 1997 to -13.6% in 1998 (Figure A.2). The IMF offered several bailout packages but demanded the closure of 16 private banks, the gradual reduction of subsidies for food and energy, increase of interest rates, the privatization of SOEs and the dismantlement of Suharto's system of patronage in which he gave monopolies to close allies and enemies in return for financial and political support. Reluctant to implement any meaningful structural reforms, Suharto did not fully commit to the terms of the IMF agreement and the situation continued to worsen. Civil unrest erupted in March 1998 when Suharto was re-elected and formed a cabinet with several of his close allies. The worst riots in Indonesian history, in which thousands of people were killed, broke out in May when Suharto decided to drastically reduce food and fuel subsidies. This social pressure forced politicians to reject Suharto's new cabinet and on May 14th 1998 he stepped down from office. The economic crisis, exacerbated by social and political unrest, deterred foreign investment for a number of years. Foreign direct investment (FDI) plummeted in 1997, reached a low in 2000 and remained negative (investors selling their assets) until 2003 (Figure A.2). Growing foreign debt from currency devaluation was combined with lower government revenues from oil exports as production continued to decline. Politically unable to lower the fuel subsidies, these soon accounted for almost a quarter of the Government's budget (Figure 5.2). Decreasing government revenues from oil exports worsened the effects of the Asian financial crisis. The effect that these events had on government expenditure on human and physical capital lasted many years (Figure 5.2).

5.2 Regime 1980 - 2005

5.2.1 Rules

Formal Rules - Strategy

Trends in welfare and oil expenditure are the two main landscape factors that shaped the rules of the electricity regime. The first plan for general policy in the sector was published in 1984 (KUBE) and concerned five main topics: (1) Energy Diversification, (2) Intensification of Energy Resources Exploration, (3) Energy Conservation, (4) Energy Pricing, and (5) Environmental.

Formal Rules - Regulations and Laws

The electricity sector saw its first major reform in 1985 with the passing of the Electricity Law No. 15/1985. The law gave full responsibility of the vertically integrated electricity supply business to the state-owned enterprise PLN. Private sector involvement was permitted but limited to captive electricity generation (for own use) or for sale to PLN through Power Purchase Agreements (PPAs). These private sector actors are referred to as Independent Power Producers (IPPs). The 2002 Electricity Law proposed the greatest changes to the sector - restructuring PLN and creating a fully competitive electricity supply business - this was largely a result of Bailout negotiations with the IMF following the Asian financial crisis. However, this was annulled in 2004 by the Constitutional Court on the grounds that the responsibility of electricity supply must remain in control of the Government. The regime remained under the umbrella of the 1985 Electricity Law until the 2007 Energy Law and 2009 Electricity Law.

5.2.2 Network of Actors and Social Groups

Although the Electricity Law of 1985 allowed the private sector to participate in electricity generation, it was only seven years later, in 1992, that the first IPPs were established (Purra, 2011). Data from the Directorate of Electricity dates back to 1994, when the share of IPPs was just 0.42% (DGE, 2007). Despite only accounting for a minor share of electricity capacity by 1997, the presence of IPPs in the regime had a detrimental financial impact on the Government and PLN as the PPAs were negotiated in US dollars. Nonetheless, IPPs helped to significantly increase electricity generation and access in the years following the Asian financial crisis.

The responsibility for policies in this period was split between the Ministries of Mines and Energy, Geology, and Industry in a relatively unorganised manner (Purra, 2011). Founded in 1978, the Ministry of Mines and Energy was Indonesia's first department of energy. However, it was not until the establishment of the Department of Energy and Mineral Resources in 2000, that the energy sector had a formalised administration and governance structure (Purra, 2011).

The Indonesian Electrical Power Society (MKI) and the Indonesian Renewable Energy Society (METI) were founded in 1998 and 1999, respectively. The MKI was made up of various regime actors and its main purpose was to facilitate discussion between stakeholders about technology, regulations and planning, and to make these discussion available to the Government. The METI was a forum that facilitates the communication, consultation and cooperation between actors in order to accelerate the development of renewable energy. The METI also became part of the World Renewable Energy Network, which connected Indonesian academics, educators, regulators, developers, and organisations to the global network of actors working on renewable energy.

Finally, with regard to residential electricity consumers, the DGE reported an increase from 9.7 million households at the start of 1990 (DGE, 2006, p. 18), to 32.1 million households by the end of 2005 (DGE, 2009, p. 35). No data is available for the number of electricity consumers before 1989/1990.

5.2.3 Material and Technical Elements

Data on electricity production in Indonesia dates back to 1990. At this time Indonesia produced 35 TWh (Figure 5.3). By 2005 electricity supply reached approximately 130 TWh - almost a four-fold increase in just 16 years. The intensification of energy resource exploration facilitated the growth in electricity production from coal, natural gas, and geothermal, creating a more diverse energy mix by 2005 - one of the priorities outlined in Indonesia's first energy plan KUBE.

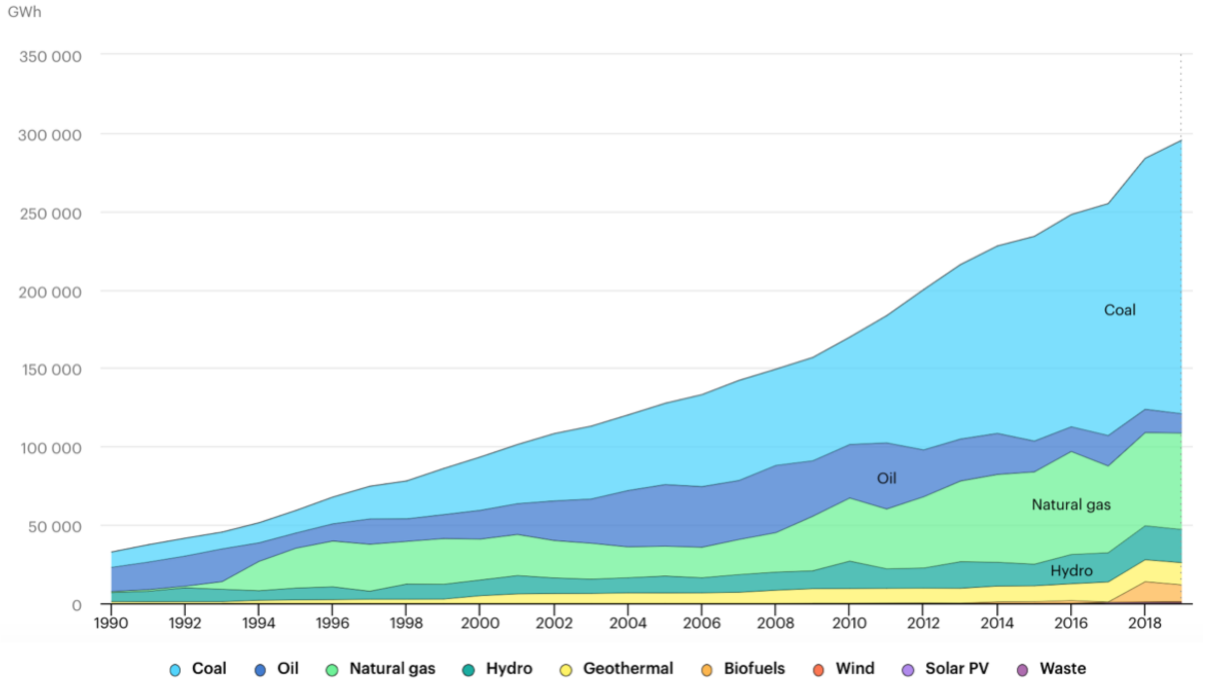


Figure 5.3: Total electricity generation 1990 - 2018 (Source: IEA, 2020b).

Transmission and distribution infrastructure expanded significantly in this period to facilitate the growth in electricity generation. Almost 14,000 km of transmission lines and 233 substations were added, reaching a total of 31,000 km and 1,080 by the end of 2005 (DGE, 2007). Almost 300,000 km of distribution lines and over 130,000 substations were added, reaching a total of 564,000 km and 254,966 by the end of 2005.

5.2.4 Energy Justice

Availability

People deserve sufficient energy resources of high quality (suitable to meet their end uses)

In 1980 just 4% of Indonesia's 147 million people, around 6 million people, had access to electricity (World Bank, 2020b; Asian Development Bank, 2016). Per-capita electricity consumption at this time was around 46 kWh (World Bank, 2020b). In the next 25 years the population increased by 54% to

226 million people. However through massive expansion of the electricity regime by 2005 Indonesia was able to supply 56% of the population, around 127 million people, with electricity. In terms of sufficiency, per-capita consumption reached 500 kWh by 2005, however this is still very low in comparison with neighbouring countries. In this period Indonesia therefore progressed immensely with respect to the availability electricity, however 44% of the population, almost 100 million people still lacked access by 2005.

Affordability

All people, including the poor, should pay no more than 10% of their income for energy services

Throughout this period electricity tariffs in Indonesia were the lowest in the South East Asia region (Purra, 2011). The automatic adjustment mechanism that was introduced in 1994 allowed tariffs to be adjusted according to fluctuations in exchange rates, fuel prices, inflation, and the level of power consumption. Although this measure resulted in slightly higher electricity prices, by 2005 electricity prices for residential users in Indonesia ranged between $ 1.50 - 4.11 cents per kWh - significantly lower than tariffs in neighbouring countries Singapore $ 9.82 cents per kWh, Malaysia $ 5.40 - 8.73 cents per kWh, and Cambodia $ 8.41 - 15.62 cents per kWh (Purra, 2011). Considering that the share of population living below the $ 3.20/day poverty line ranged between 90% in 1980 and 57% in 2005, these highly subsidised electricity prices were crucial not only for increasing access to electricity, but also limiting spending on electricity.

Due Process

Countries should respect due process and human rights in their production and use of energy

Basic human rights were severely restricted under Suharto's New Order regime. In the electricity sector these abuses related to the working conditions, recognition of land rights, and freedom to assemble and unionise. The Basic Agrarian Law of 1960 asserted national interests above traditional forms of land ownership - this is inline with Article 33 of the 1945 Constitution, which states that the nation's natural resources are to be exploited by the state for the maximum benefit of the people of Indonesia. Many indigenous communities were also legally (mis)recognised as 'rural communities' with no legal ties to territory. Throughout this period it was commonplace for these communities to be deprived of their land either using threats or actual force. These communities were resettled by force with inadequate compensation for the loss of their homes and livelihoods, often excluding them from equal opportunities of employment (Ballard, 2001). The high degree of corruption at all levels of the judiciary and the close ties with industry facilitated these energy-related human rights abuses throughout this period as these social structures persisted beyond the fall of Suharto's New Order regime and the start of Indonesia's democratisation in 1998 (Ballard, 2001).

Transparency and Accountability

All people should have access to high quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making

Under the New Order regime the Indonesian people were denied political participation and their right to free and fair electoral processes. In the electricity regime there was also no space for public participation in decision-making, nor was there access to high quality information about energy and the environment. Indonesia remained in a state of political turbulence for many years after the fall of Suharto - during this time there was still a severe lack in transparency and accountability.

Sustainability

Energy resources should be depleted with consideration for savings, community development, and precaution

In 1980 proven oil reserves were 11.6 billion barrels (Figure A.8). In the same year oil production was 1.6 million barrels per day, while consumption was still very low at 0.4 million barrels (Figure A.9). Over the next two decades oil production slowed down, while consumption grew significantly - by 2005 Indonesia became a net oil importer, with domestic consumption and production at 1.3 and 1.1 million barrels per day, respectively. During this time proved oil reserves plummeted from 11.6 billion barrels, to 4.2 billion barrels - a reduction of 64% in just 25 years. The rapid depletion of Indonesia's oil reserves is a result of unsustainable trends of production and consumption. However, Sovacool's definition of sustainability also refers to the consideration of community development. In this case the enormous revenues from high production levels (aided by the 1970s oil crises) led to an increase in public expenditure and significant reduction in poverty levels from over 90% in 1980 to 61% in 2005 considering on a \$ 3.20/day poverty line (Figures 5.2 and 5.1).

Proven natural gas reserves increased from 0.8 trillion m^3 in 1980, to 2.5 trillion m^3 in 2005 (Figure A.10). Production rose from 18.8 billion m^3, to 76.3 billion m^3 in 2005 - an increase of around 400% in just 25 years (Figure A.11). Domestic consumption, while still lower than production levels grew by over 500%, from 7.1 billion m^3 to 36.4 billion m^3.

In 1980 Indonesia's coal industry was in its infancy - production was just 0.4 million tonnes (Mt). By 2005, production had increased to 152.7 Mt and proven reserves stood at 4,968 Mt (BP, 2020). Referring to the definition shown above, coal production in this period was not unsustainable - Indonesia has very large coal reserves (the knowledge of which at this stage was limited), and the production of coal to some extent facilitated economic growth and improved electricity access (depletion with consideration to community development).

Intragenerational Equity

All people have a right to fairly access energy services

Indonesia's geographic characteristics make electricity supply extremely challenging. The bulk of added capacity in this period came from centralised power plants that would supply the largest demand centres in populous areas. Due to the lack of access to the grid, rural electrification relied on distributed power generation - typically diesel gen-sets. Electricity supply to these rural areas that have low demand and require small-scale distributed power generation is much more expensive than expanding access through centralised power in large demand areas close to existing grid infrastructure. Expansion of electricity access has therefore focused on increasing centralised power in more urban areas - this strategy has created a disparity between urban and rural access to electricity, where the rural population is marginalised by poorer access to lower quality electricity supply. Intragenerational inequity arose from the growing gap in electricity access and consumption levels between urban and rural populations. However, it is important to understand that the low electricity tariffs and high cost of supply meant that throughout this period PLN was in a state of financial turmoil unable to recuperate investments in infrastructure. In this state, the cost-effective strategy of increasing capacity to urban areas near existing grid infrastructure through centralised power sources allowed PLN to increase electricity access to far more people than would have been possible on the same budget adopting a more equitable strategy.

Intergenerational Equity

Future generations have a right to enjoy a good life undisturbed by the damage of our energy systems inflict on the world today

The noncompliance with environmental regulations, particularly for the medium-scale coal mines and rapidly expanding unregulated small-scale mines, led to dangerous emissions to the land, water, and air (McMahon et al., 2000). In terms of social impact, the human rights abuses described above, particularly the forced resettlement of rural and indigenous communities, had far-reaching impacts for future generations.

Responsibility

All actors have a responsibility to protect the natural environment and minimize energy-related environmental threats

The environmental impact assessment (AMDAL) was introduced in 1982 in response to increasing concern both nationally and internationally of the environmental impacts of rapid economic expansion

(Asian Development Bank, 2012). Although the AMDAL was consistent with international standards, in practice this was rarely implemented appropriately or enforced, resulting in significant environmental damage (Ballard, 2001). The Asian financial crisis worsen energy-related environmental damage as the Government relaxed controls of environmental performance to stimulate investment.

Resistance

Energy injustices must be actively, deliberately opposed

The Government's failure to implement significant tariff reforms since the 1980s is largely a result of successful public resistance. The most visceral example of this occurred in May 1998, when the worst riots in Indonesian history broke out in response to drastic cuts to food and energy subsidies. Thousands of people were killed. These riots were also a result of deeper tensions in Indonesia following decades of authoritarian rule, and the tough socio-economic conditions following the Asian financial crisis. The resulting pressure led to the rejection of the tariff reform, and the end of Suharto's authoritarian New Order regime. The history of widespread public resistance to tariff reforms led to the heavy politicisation of tariffs - where prior to elections, the incumbent President lowers or freezes tariffs in order to gain support, while presidential candidates promise lower tariffs to gain support (Indonesia Investments, 2020a; Purra, 2011). In this way, injustices relating to the *affordability* of energy services has been successfully resisted by the Indonesian population.

Intersectionality

Expanding the idea of recognitional justice to encapsulate new and evolving identities in modern societies, as well as acknowledging how the realization of energy justice is linked to other forms of justice e.g. socio-economic, political and environmental

The energy injustices relating to coal mining activities show clear intersections with health justice, environmental justice, and social justice - the emissions to land, water, and air have significant health impacts for local communities and workers, the mining activities themselves have detrimental impacts to the environment and non-humans, and the local communities suffer a number of human rights abuses including, but not limited to, forced resettlement. However, local support for coal mining activities was strong in many cases due to the socio-economic benefit (or justice) that these energy projects brought - miners often earned five to ten times high wages compared with traditional activities (McMahon et al., 2000). Such examples show that there is often trade-offs between different principles of justice within projects.

5.3 Niche 1980 - 2005

In response to the energy security concerns following the 1970s oil crises biomass gasification received much interest from western countries like the Netherlands, Italy, Belgium, Germany, and the US (Maniatis, 1989; Knoef, 2000; Interviewee 3 - Researcher, 2020). In a review carried out in 1989 by the United Nations Biomass Gasification Monitoring Programme (BGMP) 49 projects were identified: 16 classified as research or pilot projects, 24 power gasifier demonstration projects, and 9 commercial heat gasifiers (Stassen, 1995). All 24 power gasifiers were considered demonstration projects as they were either partly or entirely funded by foreign or national donors (Stassen, 1995). Furthermore, the gasifiers were installed in rural areas, either near industry (heat gasifiers) or near villages where the power from the plant could be used by the local community. Therefore, in addition to the **active shielding** from donors, there is a **passive shielding** aspect too due to the location, where the selection pressures of the regime are felt less intensely. For the latter point it is useful to recall that in 1980 approximately 80% of the population lived in rural areas, more than 70% of the population were living below the poverty line, and the specific energy consumption was very low - around 2000 kWh/person/year (Figure 5.1).

5.3.1 Network Formation

Composition

The network in this first period was composed of commercial and domestic end users, national and international equipment manufacturers, research institutions, engineering companies and government agencies, in addition to NGOs, banks, bi-lateral and multi-lateral aid agencies.

Most of the projects exhibited similar actor relationships: an international development agency would supply financial support through a government aid programme, and technical support through a research institution or university, which would collaborate with Indonesian actors - research institutes, universities, engineering companies, village cooperatives (for power distribution), and central government ministries and agencies. The first example was the collaboration between the Netherlands and Indonesia: through their Joint Technical Assistance programme (JTA), the University of Twente and Delft University of Technology collaborated with the Bandung Institute of Technology (ITB) to design and construct gasifiers based on wood fuel and risk husk. Their demonstration projects involved actors from local industries such as saw mills, in addition to local communities who would consume electricity (Maniatis, 1989; Interviewee 3 - Researcher, 2020). The Italian government was also active in the niche network; commissioning five gasifier projects as part of their Indonesia Wood Energy Development Project (ATA 312); a collaboration between the Indonesian Directorate General of Forest Utilisation (Ministry of Forestry) and Soft Energy Systems of Italy (Maniatis, 1989). The German government collaborated, through TUV Rheinland and the German Institute for Energy Technology and Environment, with the Agency for the Assessment and Application of Technology of Indonesia (BPPT), to test three moving-bed gasifiers (Maniatis, 1989). The United States and Belgian governments experimented with fluidized-bed gasifiers. The US aid cooperation USAID collaborated with BPPT, whereas the Belgian Directorate of Development Cooperation collaborated with the Forest Products Research and Development Centre (FPRDC) - a branch of the Ministry of Forestry based in Bogor, Indonesia.

A number of domestic engineering companies started to work on gasifiers in the 1980s and 1990s; Yayasan Dian Desa (YDD) - a small organisation formed in 1972 whose early activities were limited to clean water and sanitation, and BBI - a metal construction company which previously had very little experience with gasifiers. The advantage of BBI was that it came with a network of distributors and representatives across the country who could assist with maintenance operations and supply spare parts much faster than foreign companies.

The World Bank and UN Development Programme contributed to the niche in a data collection and distribution capacity: they jointly initiated the Biomass Gasification Monitoring Project (BGMP) in 1983 (Stassen, 1995). This was communicated at the Second International Producer Gas Conference in Bandung in 1985 (Maniatis, 1989). In this seven year programme they surveyed the progress of small-scale biomass gasification projects in several developing countries: Indonesia, Philippines, Brazil, Vanuatu, Seychelles, and Burundi.

Alignment

As projects were largely organised by international aid agencies, activities were often uncoordinated and dispersed. Several international events helped by bringing niche actors together to exchange experiences - for example the International Conference of Producer Gas, in Bandung, Indonesia in 1985, and the ASEAN Conference on Energy from Biomass, held in Penang, Malaysia in 1986. However, outside of these events, which were few and far between, there was no interaction between niche actors within Indonesia - for example the VUB/FPRDC demonstration project at the forestry research institute in Bogor was not visited by any other niche actors throughout its operation (Interviewee 9 - Independent Expert, 2020). A researcher from the Free University of Brussels (VUB), Kyriakos Mantiatis, was the first to address the lack of shared knowledge and learning experiences by travelling around Indonesia to assess the status of known biomass gasifier projects (Interviewee 9 - Independent Expert, 2020). The World Bank and UNDP later published the results of their BGMP between 1995 and 2000 (Stassen, 1995; Knoef, 2000).

Furthermore, the interaction within niche actor groups was inherently unstable due to the temporary nature of the international cooperation through which most projects were initiated. Indeed, this model in which international actors like aid agencies and technical institutes played dominant roles within niche project actor groups, had implications for the long-term stability of the network, and consequently the long-term success of projects. The involvement of these international actors was typically constrained by the timeline of the development agreement signed by the donor country - in the case of the VUB/FPRDC project the Belgian Directorate of Development Cooperation initially agreed to a four year project. During the project results were published, facilitating indirect cross-project communication where actors from different niche projects could learn from the experiences on the VUB/FPRDC project. However, once the cooperation ended and the international actors left the actor group, the publications ceased

(Interviewee 9 - Independent Expert, 2020).

5.3.2 Learning Processes

The BGMP survey in 1989 indicated that seven of the nine heat gasifiers were operating, compared to just 11 of the 24 power gasifiers (Stassen, 1995). Projects failed due to a range of technical, financial, and institutional reasons. Table 5.1 shows some of the variation between six power gasifiers - four of which were subject to in-depth monitoring through the BGMP, while the other two were investigated by Maniatis, 1989.

Table 5.1: Characteristics of six power gasifiers that were subject to monitoring (Sources: Stassen, 1995; Maniatis, 1989).

Site	Capacity	Reactor	Gas-cleaning	Engine	Biomass	Application
Balong	20 kW	downdraft	cyclones, stone rockwool, impingement filter	diesel	rubber wood	community electricity
Sebubuk	30 kW	downdraft	spiral flow separator, scrubbers, fabric filter	Otto	waste wood	industrial electricity
Majalengka	15 kW	cross-draft (open core)	cyclones, scrubbers, coconut fiber	diesel	rice husk	community electricity
Lembang	10 kW	ferrocement downdraft	bag filter	Otto	charcoal	electricity
ITB	15 kW	downdraft		diesel	rubber, teak	
Randublatung	60 kW	downdraft		diesel	teak	

Technical and Infrastructural Developments

Early experiments exhibited some variation in terms of end-use, end-users, and gasifier type - which in turn influenced the design of the pre-treatment, flue gas cleaning, and power generation units. The BGMP developed a unified set of measurement protocols which allowed for a comparative assessment of technical performance between projects. A wide range of variables were measured in order to assess the technical performance of the gasifier plants: pressure, temperature at different locations in the reactor, gas flowrate, fuel consumption, emissions, and the composition of lubrication oil and gases (Knoef, 2000). Dust and tar content of the producer gas are key factors that determine the performance of the power plant and have important implications for the expected lifetime of the plant and required maintenance. Table 5.2 shows the acceptable and preferred quality of producer gas for modern engines, while Table 5.3 shows the results from the BGMP tar and dust experiments.

Table 5.2: Acceptable and preferable producer gas qualities for use in modern engines (Source: Knoef, 2000).

Parameter	Acceptable	Preferable
Gas heating value (kJ/Nm^3)	>2500	>4200
Gas dust content (mg/Nm^3)	<50	<5
Dust particle size (μm)	<10	<1.0
Gas tar content (mg/Nm^3)	<100	<50

Table 5.3: Tar and dust measurements from power gasifiers in Indonesia (Source: Knoef, 2000).

Installation	Fuel	Dust content (mg/Nm^3)		Tar content (mg/Nm^3)	
		Raw gas	Clean gas	Raw gas	Clean gas
Balong	Wood	210 - 470	90 - 150	230 - 1600	630 - 2150
Jambi	Wood	-	40 - 90	-	110 - 420
Majalengka	Rice husk	900 - 3400	<50	3600 - 13,800	1000 - 2300
Lembang	Charcoal	-	<0.01	-	<0.01

With the exception of the Lembang plant, every plant in Indonesia subject to this more in-depth monitoring by the BGMP showed that dust and tar levels in the producer gas did not meet the requirements for power generating engines. Through variation of process conditions the experiments led to general learning about the sensitivity of tar and dust levels to different process conditions; load level, feedstock, and reactor type. In terms of feedstock, gasification of non-wood feedstocks, particularly rice husks, led to high dust and tar contents in the flue gas. The lowest levels of dust and tar were found for charcoal, as per the expectations of the researchers. In terms of process conditions tar levels were shown to decrease at higher flowrates due to the higher temperatures reached in the gasifier. The experiments showed the opposite relation with dust levels, which increase with increasing load levels. Finally, down-draft gasifiers are preferred as they were designed specifically to minimise the tar content of the gas.

Comparison of the tar and dust content in the raw (untreated) gas, and the clean gas allowed for conclusions about the effectiveness of different gas cleaning units/series of units:

- *"Cyclones and baffle separators are not effective in reducing the dust content of the gas to acceptable low levels unless very high pressure losses are accepted" (Knoef, 2000, p. 43).*
- *"Fabric (bag) filters show the best performance as dust separators and allow excellent separation... to avoid condensation of tars and water on the filter surface... the gas temperature is normally kept at 120 - 150 °C. This requires relatively expensive filter materials" (Knoef, 2000, p. 43).*
- *"Wet scrubbers are reasonably effective for tar and dust removal although they do not lower the gas tar content sufficiently for engine application... As scrubbers generally use large amounts of water, their application may give rise to water contamination problems" (Knoef, 2000, p. 43).*
- *"Dry gas cleaning systems are recommended rather than wet cleaning systems since the concern on environmental and safety issues is generally low" (Knoef, 2000, p. 45).*

User Experience

The experience of the end users was generally found to be positive - talking about TU Twente and ITB's demonstration plants in Balong and Jayi, Mantiatis wrote:

"The social impact has been positive and the villagers appreciate the supply of electricity, especially because of television which keeps them in closer contact with the world" (Maniatis, 1989, p. 226).

"In general after 1000 h of operation the unit functioned properly and the villagers appreciated the supply of electricity" (Maniatis, 1989, p. 227).

Data regarding end-user experiences with projects is very limited - the reviews by Maniatis, 1989; Stassen, 1995; Susanto, 2018 give some indication of their experiences while the certain power plants were operating. However, since many projects struggled with (socio-)technical problems throughout their operation that led to either prolonged periods of shutdown or even termination of the project, it is reasonable to speculate that user experiences in most cases were not as positive as the above quotations in the long-term.

Furthermore, it is important to consider the experiences of the plant operators. The operation of gasification plants were considerably more troublesome and dirty compared to stand-alone diesel power plants.

"they are reluctant to operate the gasifier since the additional work is time-consuming and dirty." (Maniatis, 1989, p. 226)

Recalling that the particle size, moisture content, and chemical compositions (and consistency thereof) strongly influence the performance of the gasification plant (Section 4.1.3) - a key success factor for plants is therefore the motivation and diligence of its operators. For example, in Randublatung the operator of a gasification plant at a saw mill did not cut the feedstock to the recommended size, which caused excessive tar production, resulting in a hole in the gasifier after just 800 hours of operation (Maniatis, 1989). Susanto, 2018 suggests that the lack of motivation could be because:

"[translated from Indonesian] people do not understand or do not feel the need to diversify energy sources, considering that fuel is still affordable both in terms of price and availability" (Susanto, 2018, p. 28).

Comparing the favourable performance of the Balong project with less successful projects using similar equipment, a key success factor was the extensive technical support and training that was provided by ITB over a prolonged handover period of several years - this was found to create much more motivated and competent staff (Stassen, 1995; Susanto, 2018; Interviewee 2 - Researcher, 2020).

Industrial Development

The degree of variation between actors groups in their sourcing of materials allowed the reviews of Maniatis, 1989; Stassen, 1995; Knoef, 2000 to draw some conclusions about the advantages and disadvantages of each option. In projects using imported technology, initial technical problems often resulted in prolonged shutdown of the equipment to await foreign technicians, equipment, and spare parts. The long periods of inactivity discouraged gasifier owners and operators. Projects using locally manufactured equipment thus benefited from cheaper equipment, and more readily available spare parts and maintenance. However, maintenance services within Indonesia were still costly and often unavailable for gasifier installed in remote locations (United Nations and World Bank, 1990). Furthermore, locally manufactured equipment was found to be of lower quality and less reliable. Niche actors therefore continued to experiment predominantly with foreign manufactured gasifiers. From the data collected there is no evidence of actor groups changing their gasifier supplier (domestic to foreign) in response to experiences in earlier projects.

Biomass Potential

In 1981 the World Bank published their Energy Assessment of Indonesia; estimating that the potentials for sustainable forest biomass and agricultural residues were 650 million t/yr and 90 million t/yr, respectively (cited in (United Nations and World Bank, 1990)). However due to the relatively undeveloped state of the small-scale gasifier niche only wood, rice husks, coconut shells, and charcoal were considered as suitable feedstocks. The resource size of residues from wood residues from logging, wood processing industries and rubber estates, in addition to rice husks and coconut shells was estimated at 47 million million t/yr. The second volume of the UNDP/World Bank Pre-Investment Study provided the location and availability of feedstocks, however this was not found to be currently available online.

Prior to the UNDP/World Bank studies there was no published overview of biomass feedstock potential in Indonesia. Although it is unclear to what extent the findings of these studies were used by niche actors, they nonetheless contributed to a greater availability of information regarding biomass potential. As many of the projects were well underway by the time the Volume I and Volume II Pre-Investment studies were published (1990), it is clear that niche actors were already aware, albeit to varying extents, of biomass potential. However, due to the absence of published data by actor groups at this time it is not clear how comprehensive their knowledge of biomass feedstock potential was.

Policy and Regulatory Environment

As all of the power gasifier projects were (1) either partly or wholly funded by the Indonesian government or international donors, and (2) located in rural locations, they were largely insulated from the selection pressures of the policy and regulatory environment. From the data available on niche activities at the time is difficult to determine to what extent actor groups *learnt* about the policy and regulatory environment. The available review documents indicate that through learning about the economic performance of gasification plants in practice, actors were able to learn that the current fossil fuel subsidies, that facilitated wide access to cheap diesel fuel, were barriers to wider adoption of the technology (Maniatis, 1989; United Nations and World Bank, 1990; Stassen, 1995; Knoef, 2000; Susanto, 2018).

Business Models

Commercial interest was dependent on the cost, and the potential capacity of the system. The high cost of imported gasifiers and supportive systems were also prohibitive for commercial development (Stassen, 1995). The economic case was only viable in remote locations that had limited access to cheap diesel (200 Rp/litre) (Maniatis, 1989). The ferrocement gasifier was considered an interesting option because of its low capital cost, however, the relatively high price of charcoal, compared with commercial liquid fuels, rendered the current design economically unviable in the Indonesian context and so the technology was never commercially introduced or marketed. In terms of capacity, two market studies from the United Dutch Consultants and the CESSEN-ADB studies revealed that commercial users would need between 150 and 300 kW (studies cited in (Maniatis, 1989). This demand was much larger than the gasifiers being developed at the time, which ranged from 15 to 65 kW. The apparent unsuitability for commercial use reinforced the perception that this technology would only be suitable for rural electrification where access to diesel is limited and demand for power is low.

The non-commercial projects were funded by bi-lateral aid agencies. In the financial assessment of these subsidized projects the owners typically did not account for depreciation costs since the capital cost of the plant was paid for by the donor. Presenting such data can present a “far too optimistic picture on the viability of small scale gasifiers” (Knoef, 2000, p. 40).

Second-Order Learning

There were no examples of second-order learning identified in this period.

5.3.3 Voicing and Shaping Expectations

Expectations of biomass gasification in the early 1980s were vague and incoherent nationally, but also internationally. International interest in the technology was only renewed following the two oil crises in the 1970s. The Dutch, German and Swedish development agencies (DGIS, GIZ and SIDA respectively) started funding small-scale projects in developing countries based on the expectations that the technology is suitable for rural electrification and that it could be suitable for larger scale electricity and heat production once developed further. The variety of demonstration projects in Indonesia illustrates these expectations.

Early results from the ITB demonstration projects were able to attract attention from President Suharto who, on a visit in 1985, committed to funding six additional biomass gasification projects in West Nusa

Tenggara, East Nusa Tenggara, Maluku, Irian Jaya, Kalimantan and Sumatra. The gasifiers ranged from 15 - 100 kW, four were used for rural electrification, two for the wood industry, five of the six were fuelled by wood, and one with rice husks (Maniatis, 1989). This is a clear example of mutually reinforcing niche nurturing processes: the results from the ITB experiments (learning processes) positively influenced expectations of the niche, which led to further experiments, involving more actors and added to the scale of the learning processes. The characteristics of the new projects reflect the preference of small-scale wood gasifiers for rural electrification purposes.

Many of the projects were plagued with technical difficulties and some projects did not manage to operate for longer than a few hours at a time. Power gasifiers in particular suffered from these technical difficulties, due to the more stringent requirements for the flue gas entering the engine. This difference was made clear in the BGMP survey, which reported that 78% of the heat gasifiers were operational, compared to just 46% of the power gasifiers (Stassen, 1995). Expectations of heat gasifiers were also low due to concerns over the scale at which the technology could be implemented - the survey from the United Dutch Consultants and CESSEN-ADB showed that commercial users would require 150 - 300 kW, which is an order of magnitude greater than the demonstration projects.

Prior to the UNDP/World Bank BGMP there was no comprehensive analysis on biomass resource potential, biomass gasification technologies, or their technical and economic viability in the Indonesian context (United Nations and World Bank, 1990). Expectations prior to this study were therefore generally of low quality as they were not supported by experimental results. Through the seven year monitoring programme the BGMP collected real data from operating gasifiers in Indonesia. Following the competition of this programme, new high quality expectations were formed:

"In short, power gasifiers must be considered as an inferior technology for reliably delivering shaft-power, when compared to the standard alternative - a petroleum fueled engine. Significant additional R&D is needed to improve field reliability or, alternatively, more stringent standards on fuel quality, system design and operator skills must be implemented. Even when assuming technical readiness along with the necessary additional costs of operation and maintenance to equalise reliability, the economic potential for power gasifier applications in Indonesia is small" (United Nations and World Bank, 1990, p. 31).

From the data collected in this study it appears that ITB/Indonesian government actor group was the only one to continue to implement projects following competition of the BGMP in the late 1990s. The expectations of biomass gasification at the end of this transition period were undoubtedly lower than in the beginning, and of higher quality. The withdrawal of several actor groups from the niche towards the end of the period is however not purely caused by poor results - the withdrawal of international donors, which sponsored the majority of niche activities in this period, was also due to decreasing landscape pressures as a result of stabilising oil prices (Interviewee 9 - Independent Expert, 2020).

5.3.4 Energy Justice

Availability

People deserve sufficient energy resources of high quality (suitable to meet their end uses)

Projects in this period had a variety of end-users; local communities that use the electricity in households for lighting or television, local communities that use the electricity for productive purposes like irrigation, and industrial users. Projects were by in large implemented in rural settings (passive shielding), where access to energy resources, particularly electricity was limited. Considering that in 1980 only 20% of the population had access to electricity, successful niche projects contributed to the availability of energy resources. However, the high failure rate of power gasifiers meant that the potential contribution of systems to energy resource availability was not fully realised - around 54% of power gasifiers were not operational at the time of the BGMP, while the vast majority also suffered socio-technical problems that led to poor performance like low utilisation rates (Stassen, 1995).

Affordability

All people, including the poor, should pay no more than 10% of their income for energy services

Information regarding the electricity supply cost from niche projects in this period is very limited. The results for a few projects will be discussed but this cannot be assumed to be the case for all projects due to the variation of setting, feedstock, and plant design. Table 5.4 shows the results from three niche projects in comparison to the lowest PLN tariff at the time, and the typical cost of kerosene for lighting. Niche projects delivered electricity at a slightly higher price than the lowest tariff available from PLN at the time. However, due to electricity subsidies the cost of electricity was typically much lower than the actual cost of generation. Furthermore, projects that supplied electricity to community households substituted kerosene that was burned for lighting. These projects were able greatly reduce the energy expenditure for these households, which would otherwise spend around 7000 Rp/month on kerosene fuel.

Table 5.4: Electricity cost from niche projects compared to alternatives

Electricity supplier	Electricity supply (W/household)	Cost (Rp/(W month))	Cost (Rp/month)	Reference
Balong gasification project	30	75	2250	Maniatis, 1989
Jayi gasification plant	-	200	-	Maniatis, 1989
Maluku gasification plant	60 - 100	41.7 - 50	2500 - 3000	Susanto, 2018
PLN (lowest tariff)	60 W	29	1740	Maniatis, 1989
Kerosene	-	-	7000	Susanto, 2018

Intragenerational Equity

All people have a right to fairly access energy services

Through operating in remote areas niche projects were able to contribute to greater intragenerational equity as these end-users were marginalised by the electricity regime through poor access to energy services (**availability**) and consequently spent more on these services (**affordability**).

Responsibility

All actors have a responsibility to protect the natural environment and minimize energy-related environmental threats

In this period there were a few examples of actors making decisions based on concern for the environment. In 1982 the BPPT/TUV Rheinland actor group decided to cease operation of their updraft gasifier in the BPPT Research Centre due to high phenol concentration in the condensate and high tar levels. Later in 1983 when experimenting with two downdraft gasifiers in Picon, the actors observed that at ideal operating conditions a condensate with high phenol concentration was produced. For one of the gasifiers the actors were able to increase the cool gas temperature by 10°C, accepting a 5% drop in efficiency to ensure that no condensate was produced. However, the other downdraft gasifier used a water gas scrubber cooler which produced significant amounts of condensate with high phenol concentrations. Since no solution was found for the treatment of the condensate the actors decided to terminate the test runs at the end of 1984. These examples show that actors made concerted efforts to minimise the environmental threats of the projects, and when this could not be achieved, the projects were terminated.

Intersectionality

Expanding the idea of recognitional justice to encapsulate new and evolving identities in modern societies, as well as acknowledging how the realization of energy justice is linked to other forms of justice e.g. socio-economic, political and environmental

The gasifiers installed in Picon, West Java offer an example of how niche projects, if successful could have significant socio-economic impacts in rural communities. The producer gas from the gasifiers was used to generate electricity for the irrigation of around 45 ha rice fields, while the exhaust heat was used to dry the wood feedstock. The irrigation of the fields would allow farmers to harvest rice twice a year, which could increase their income by an estimated 28 million IDR/year (Maniatis, 1989). In the context of the high poverty levels described above, such an outcome would be very favourable in terms of socio-economic justice.

5.4 Summary

Niche projects were **actively shielded** by Western oil-importing countries that were under pressure during the oil crises to investigate alternative energy sources. Small-scale demonstration projects were implemented in rural areas that also benefited from **passive shielding** from regime selection pressures. The niche **network** was comprised of multiple autonomous actor groups of similar composition - a foreign government collaborating with the Indonesian Government, the foreign government contracting a research institute or private companies to implement the project in collaboration with an Indonesian implementing partner or manufacturer. These early **experiments** in the field allowed the technology developers (mainly foreign research institutions such as TU Twente) to learn about the socio-technical performance of the technology outside of the laboratory environment. The learning concerned the level of tar production under the local conditions which included the available feedstock, the operation of the plant by trained local people, and the societal impact of the projects. The majority of projects failed due to poor operation of the gasifiers, which caused high tar production and consequently equipment failure. Experiences from these early niche experiences lowered the **expectations** of the niche. The majority of niche activities seized in the later 1990's in the context of domestic political turbulence and stabilising global oil prices which marked the end of donor interest in biomass gasification.

The landscape pressures that regime develops sought to alleviate mainly concerned the high prevalence of poverty and poor access to electricity across the country - related to the *availability*, *affordability*, and *intersectionality* (socio-economic) principles of energy justice. Falling domestic production and rapidly increasing consumption of oil motivated early energy strategy to diversify the energy mix and reduce the share of oil in final consumption. Small-scale diesel power plants were the main option for electricity supply to rural areas where centralised power would be prohibitively expensive. Despite this clear opportunity to investigate alternative the Government did not seriously invest in the development of any such alternatives.

6 2007 - 2016: Improving Regulatory Environment

6.1 Landscape 2006 - 2016

The decentralisation of power following the 1999 reform meant that local authorities not only controlled a greater share of revenues from local resources, but also controlled the issuance of licences for the extraction of natural resources. This led to mining and logging on an enormous scale in resource-rich areas like Sumatra, Java and Kalimantan. Between 2001 and 2019 Indonesia lost 26.8 Mha of tree cover - commodity driven deforestation has been the main driver of tree cover loss since 2001 (Figure 6.1. Tree loss has resulted in the emission of 10.9 Gt CO_2 (Global Forest Watch, 2020), and created large areas of unproductive degraded land. By 2014 the Indonesian Climate Change Centre estimated that 78 Mha of land was degraded - 41% of Indonesia's total land area (Indonesia Climate Change Center, 2014).

Developments relating to the international articulate of the climate change landscape pressure are very relevant, particularly those relating to land-use and land-use change (below).

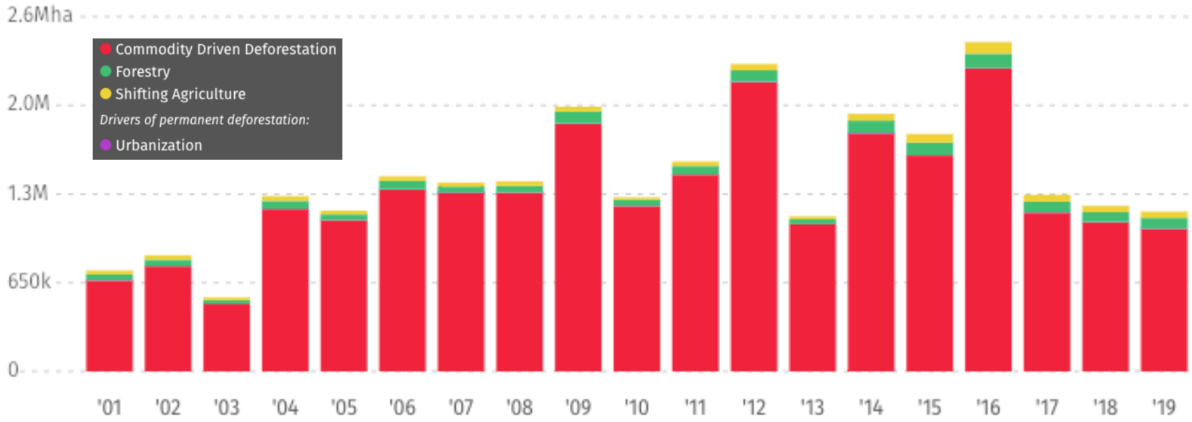


Figure 6.1: Annual tree cover loss by dominant driver in Indonesia (Source: Global Forest Watch, 2020).

Climate change landscape pressures have two dimensions - the reduction of emissions from *sources*, and the protection and expansion of carbon *sinks*. However, the Clean Development Mechanism (CDM), that was introduced by the Kyoto Protocol of 1997, did not support emission reductions from deforestation and forest degradation (REDD) due to anticipated difficulties in its implementation. In the context of socio-economic and socio-political turmoil in Indonesia surrounding the Asian financial crisis and the fall of Suharto's New Order regime, Indonesia was not engaged with the global climate movement at this time. However, REDD received substantial attention following COP 13 that was held in Bali, Indonesia in 2007. The REDD+ framework was further developed at COP 19 in Warsaw 2013 and by 2015 most of the final decisions regarding the REDD+ framework had been made. In the same year, the landmark COP 21 signified the start of a more coherent global response to climate change. The central goal of this agreement is to limit the rise of global temperatures to "well-below" 2°C above pre-industrial levels (UNFCC, 2020). The climate change landscape pressure not only affects the niche through a shift in regime rules, but also through increased availability of resources from the international community: between 2013 and 2018 global climate finance flows increased from \$ 342 billion to \$ 546 billion, reaching a peak of \$ 612 billion in 2017 (Buchner et al., 2019).

The landscape pressure to reduce oil consumption intensified in this period due to increasing imports (due to decreasing domestic production and increasing domestic consumption) and rising international oil prices, which increased dramatically from an average of \$ 50.5 per barrel in 2006, to a peak in 2012 at \$ 109.5 per barrel (Statistica, 2020). In 2013 and 2014 Indonesia oil trade balance reached its minimum at -3% of the GDP - see Figure A.6 (G20 Peer-Review Team, 2019).

The structural transformation of Indonesia's employment from the agriculture sector to the services sector became more pronounced in this period: employment in agriculture fell from 42% in 2006 to 32% in 2016, while employment in services increased from 39% to 46% (Figure A.3). In this time Indonesia's

GDP rose dramatically from $ 365 billion to $ 932 billion, and electricity consumption almost doubled from 118 TWh to 226 TWh (World Bank, 2020b; IEA, 2020b). This increase in electricity demand put significant pressure on the electricity sector and was one of the main factors shaping energy strategy and regulations governing the regime in this period.

6.2 Regime 2006 - 2016

6.2.1 Rules

Formal Rules - Strategy

Falling oil production, and increasing domestic consumption made Indonesia a net importer by 2004 (Figure 5.2). Politically unable to increase fuel tariffs, the oil subsidies became a massive burden on the Government - in the years before 2006 these accounted for 10 - 25% of government expenses (Kaneko, Luthfi, and Senevirathne, 2017). The pressure from these landscape developments led to a reorientation of the electricity sector. This shift is captured by the quantitative targets set by the National Energy Management Blueprint, which replaced KUBE in 2006:

- **Reduce share of oil in final consumption to below 20%**
- The share of specific sources in final consumption should be increased:
  - Coal > 33%
  - Liquefied coal > 2%
  - Natural gas > 30%
  - Geothermal > 5%
  - Biofuel > 5%
  - Other renewable energy > 5%
- Reduce energy elasticity to < 1%
- Improve energy infrastructure

This plan was given a legal basis in 2007 with the passing of Law No. 30/2007 on Energy, which set several main objectives for the sector: (1) energy independence, (2) ensure availability of energy sources, (3) ensure optimal, integrated and sustainable management of energy sources, (4) efficient utilisation of energy sources, (5) ensure public access to energy and (6) ensure environmental sustainability. A shift in priorities can be seen here in the newly listed objectives - energy independence, energy availability, and energy access - and the inclusion of Indonesia's first renewable energy targets. In terms of the new objectives, the first two are explained by increasing expenditure on oil imports and the fuel tariffs mentioned above, however, ensuring public energy access may be explained in the context of rising GDP (Figure 5.1) and strong growth in electricity supply (Figure 5.3). This new objective, improving energy access, represented a new priority in the electricity sector. The 2006 National Energy Management Blueprint and the 2007 Energy Law are both important developments for the niche as they explicitly incorporate energy access and renewable energy into the long-term sector planning. Targets for both of these priorities were set and revised throughout this period.

Electricity supply was put under pressure by strong economic growth and a growing middle class - by 2015 Indonesia's power plants were operating at full capacity to cover the average demand and were unable to cover spikes in demand. During demand peaks, PLN imposed rolling blackouts in critical demand centres to avoid full system outages (Tharakan, 2015). By 2015 consumers on average experienced 15 blackouts each year (Tharakan, 2015). During these blackouts facilities like hospitals were forced to use costly emergency backup power generation (typically diesel). In response to concerns of electricity shortages the Government introduced several Fast Track (FT) programs to accelerate capacity addition. FT I was introduced in 2006 under Presidential Decree No. 71/2006 and focused on adding 9,975 MW from new coal-fired power plants. FT II was initiated in 2009 by Presidential Decree No. 59/2009 and sought to add 4,000 MW geothermal power, 1,753 MW hydropower, 64 MW through coal gasification, 280 MW from natural gas, and 3,000 MW from coal. Both FT I and FT II faced severe delays due to technical issues, lack of access to funding, and contested land rights. By 2015 only 57% of the additional capacity planned under FT I (2006 - 2010) had been installed (Tharakan, 2015). FT III, was announced in 2015 which would add 35 GW of power by 2019. Like the previous two programs FT III relies heavily on coal power: 56% of new capacity will be from coal-fired power plants, which is supplemented by natural gas (36%), hydropower (4%), geothermal (2%), and other energy sources (2%).

In 2009 65% of Indonesians had access to electricity (World Bank, 2020b). The government implemented a range of projects and programmes over this time period which aimed to improve access to electricity and facilitate development in rural communities: the National Program for Community Empowerment in Rural Areas (PNPM-Rural) in 2007, the MEMR SHS programme in 2008, and the Green PNPM in 2012 focusing on renewable energy (Sambodo, 2015). Although the more recent Widodo administration (2014 - present) has been more explicit in their framing and communication of an energy justice vision (discussed in Section 7.2.1), efforts to improve the **availability** and **affordability** of electricity access were also evident throughout previous administrations. The Government's 2010 - 2014 Mid-Term Development Plan (RPJMN) set an electrification target of 80% by 2014. To achieve this target the Government estimated that 3,000 MW additional electricity generation capacity would need to be added each year (Bappenas, 2010). Government plans for electrification however have focused on increasing centralised power generation and expanding grid infrastructure, which proved effective for boosting electrification rates in more centralised industrial areas, but came at the expense of rural communities, that remained without access to electricity.

However, in their in-depth analysis of **electrification strategy** in Indonesia, the ADB revealed a disconnect between government targets, and the resources committed to achieving these targets (Tharakan, 2015). Insufficient funding levels, inefficient and cumbersome funding mechanisms, and the absence of a scalable framework for sustainable off-grid supply were the three main inadequacies in the current approach. In terms of funding levels; despite government targets to achieve universal electricity access, by 2015 no rigorous national analysis had been conducted to determine the funding level necessary for achieving this target. In the absence of such a study, the ADB presented a high cost case of \$ 1,760/household for rural locations like Sumba Island, and a low cost case of \$ 300/household assuming that 70% of new connections will be in-fill connections, and 30% will require publicly funded grid extension at \$ 1000/ household. Considering the number of households without electricity, the ADB estimated that \$ 3 billion - \$ 18 billion would be required. This is 8 - 48 times that of the current funding level - their analysis highlighted the **massive disconnect between government targets and the resources they have committed to achieving these targets**. The second inadequacy was related to the funding mechanism; in particular the lack of a single national least-cost electrification plan, which could form the basis for planning and funding allocation. Without such a plan the limited public funding is used inefficiently as several agencies undertake electrification programs in an uncoordinated manner using their own criteria and processes. Lastly, private sector sustainable off-grid projects have been implemented in an ad-hoc manner, and faced a number of challenges from the cumbersome implementation process (e.g. lengthy regulatory approval processes) and lack of supportive financial incentives. Off-grid projects implemented by line ministries, PLN, and local governments have had very high failure rates due to insufficient financial and technical support for long-term operation and maintenance (Tharakan, 2015).

The pressure from the international community for all countries to commit to climate change mitigation strategies was a key landscape pressure that intensified over this period. In 2014 the National Energy Council published the National Energy Policy (NEP), which set new targets for the electricity sector, including a much more ambitious target for new and renewable energy:

- New and renewable energy at least 23% by 2025 and 31% by 2050;
- Oil less than 25% in 2025 and less than 20% in 2050;
- Coal minimum 30% in 2025 and minimum 25% in 2050; and
- Gas minimum 22% in 2025 and minimum 24% in 2050

This target is an indication of the Government's intention to transform the electricity regime. Specific targets were set for bioenergy 10% , geothermal 7%, hydropower 3%, and other renewable energy sources 3%. This division reflects growing expectations of bioenergy sources as these now account for the largest share of the renewable energy target. Just as in the National Energy Blueprint of 2006, the NEP shows the long-term strategy to limit oil consumption and ensure that coal and natural gas both make up significant shares of consumption.

Indonesia ratified the Agreement in 2016 and pledged to reduce emissions by 26% compared to a 'business-as-usual' scenario by 2020, this is their *unconditional* nationally determined contribution (NDC). The government also put forward a *conditional* pledge of a 41% reduction in emissions, conditional on support from the international community (Indonesia, 2015). The majority of reductions stem from emissions relating to land-use and land-use change - just 9% of these reductions are targeted to come from the energy sector, and so do not imply a significant overhaul of the existing energy system (Bappenas, 2020). **This target does however articulate two dimensions of the climate change pressure** - the need to reduce emissions from energy use, and the need to reduce emissions from land-use and land-use change. This is a particularly important development for the biomass gasification niche as it spans across both the energy sector, and the agriculture and forestry sectors.

Formal Rules - Regulations and Laws

Inline with the growing attention to rural electrification the 2009 Electricity law obligated PLN to improve supply to remote, underdeveloped regions through additional generation capacity and expansion of on-grid and off-grid infrastructure. The law also provided a greater opportunity for the private sector to participate in the transmission and distribution - any entity could supply, transmit, and distribute power, but only one entity could hold the electricity supply licence for each operational area, and PLN held first refusal in all areas. This law did not have a great impact as PLN has predominantly excised their right to first refusal (pwc, 2018). The government and PLN have focused on grid expansion to increase electrification, and devoted much fewer resources to developing off-grid power through their (few) rural electrification programs. In 2012 a number of measures were introduced that support rural electrification: firstly, IPPs were allowed to transmit and distribute power in off-grid projects at PLN's digression, and secondly, the Government introduced the special allocation fund (DAK) through Ministry of Finance Regulation No. 201/PMK.07/2012, to promote the utilisation of renewables at the local level. The DAK was supported by technical guidelines provided in MEMR Regulation No. 3/2013, which focus on micro-hydro, solar PV and household biogas digesters. In 2016 MEMR introduced Regulation 38/2016, which aims to accelerate small-scale electricity generation in rural electrification in remote, border, and inhabited small islands.

In the context of growing awareness and concerns over land-use change the 2009 Environmental Law No. 32/2009 (implemented by Minister of Environment Regulation No. 5/2012) introduced requirements for environmental analysis and permits to certain projects. Solar, wind and biomass power plants >10 MW were since required to perform an environmental impact assessment and secure environmental permits.

In order to stimulate development of generating capacity from these sources the Government introduced Feed-in-Tariffs (FiTs) for small biomass (<10 MW), biogas and municipal waste power plants in 2012. FiTs were extended to incorporate: small-hydro (<10 MW) at \$ 0.12/kWh (MEMR regulation 19/2015), geothermal at \$ 0.12 - 0.28/kWh (MEMR Regulation 17/2014), and solar PV at \$ 0.15/kWh (MEMR

Regulation 19/2016). To further incentivise the expansion of energy from biomass sources MEMR and the MoEF signed a Memorandum of Understanding (MOU) in 2014 to accelerate the use of industrial tree plantations (HTI). Together with the FiT this was considered necessary for stimulating biomass power production (Pirard, Bär, Dermawan, et al., 2016).

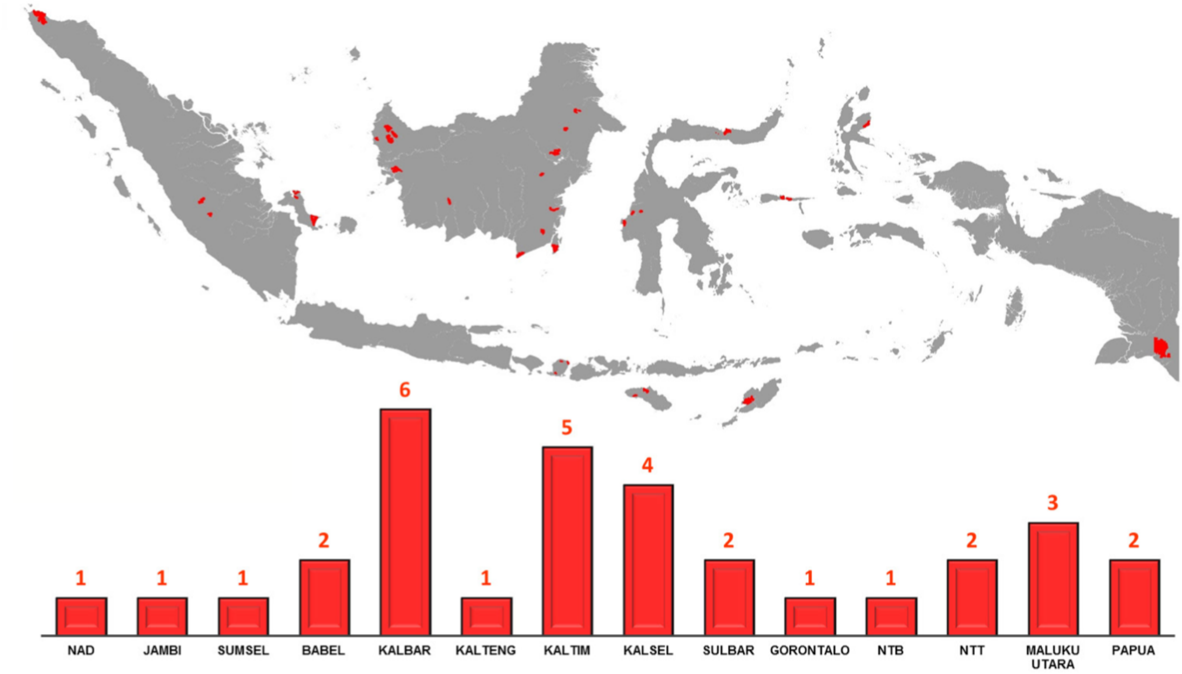


Figure 6.2: Locations of industrial tree plantations (Source: Pirard, Bär, Dermawan, et al., 2016).

Since 2014 32 HTI concession holders have revised their plans to include energy production (Figure 6.2). However, there is yet to be a successful commercial demonstration project (Pirard, Bär, Dermawan, et al., 2016). Developments in competing industries, and in the international environment can have a significant impact on the domestic use of wood (Interviewee 4 - Researcher and Industrial User, 2020). For example, decreased wood chip supply from Australia, a major exporter, has created higher prices for Japan and China, two major importers in the region (Hawkins Wright, 2019). Domestic consumers of wood chips are unable to compete with high export prices. A future large-scale wood-based energy system will need sufficient regulations in place to protect domestic consumers from strong export markets.

6.2.2 Material and Technical Elements

Three trends in electricity generation between 2006 and 2016 are visible from Figure 5.3. First, the increasing dominance of coal power: generation from coal power plants rose from 58.6 TWh to 135.4 TWh; increasing from 44% to 55% of the mix (IEA, 2020b). The second trend is the decreasing share of oil, which fell from 29% to just 6%. The third trend is the increasing use of natural gas, from 19.4 TWh to 65.7 TWh by 2016. These trends in generation technologies were the result of the energy strategy and regulatory developments described above.

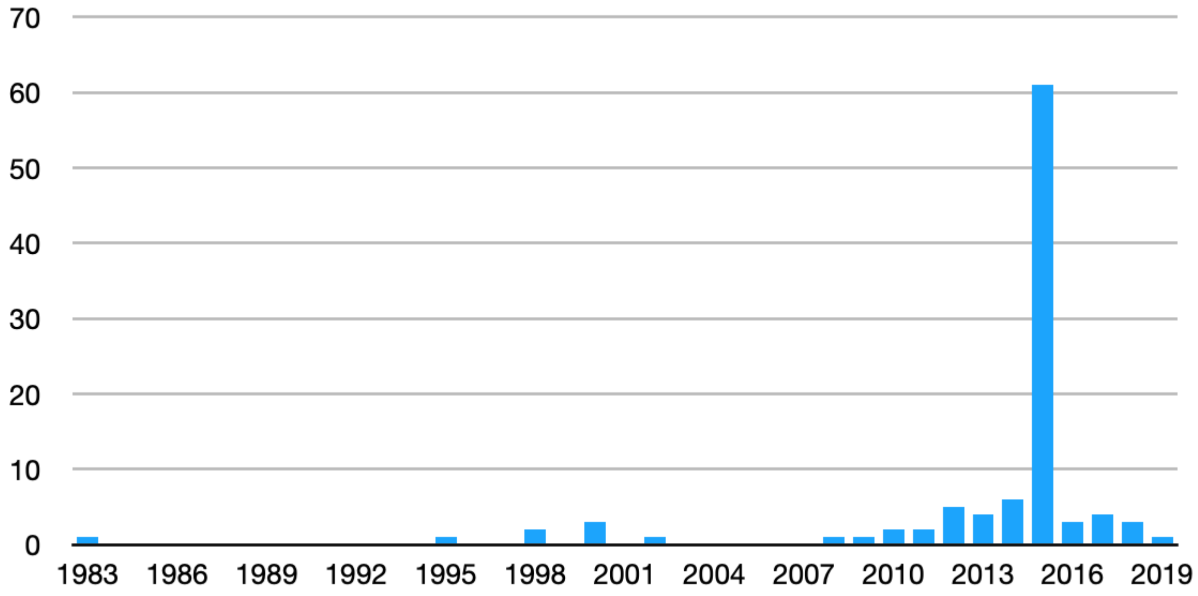


Figure 6.3: Number of biomass power plants (PLTBm) reaching commercial operation (Source: author, produced using information from DGNREEC, 2019).

Although the increase in bio-based electricity generation is not visible until 2018, the number of biomass power plants reaching the commercial operation stage increased significantly in 2015 (Figure 6.3). The term 'PLTBm' does not differentiate between gasification and direct combustion. A closer inspection of the PLTBm projects listed by the DGNREEC reveals that all projects use direct combustion (DGNREEC, 2019). Furthermore, the majority of PLTBm plants are owned by oil palm companies who make use of readily available residues to generate power for the local grid. A good example of these projects is the Listrindo Kencana Biomass Power Plant: a 12 MW power plant located inside a palm oil plantation that uses palm residues (empty fruit bunch and palm kernel shell) as the primary fuel for electricity generation (UNFCCC/CCNUCC CDM, 2013). The plant was motivated by poor electricity supply which hindered development on the island of 217,000 people - before the project the grid on Bangka island had 40 MW installed power, however these diesel generators were frequently unable to meet the demand, causing frequent blackouts (UNFCCC/CCNUCC CDM, 2013). This project was supported by the Danish Ministry of Climate and Energy, the Danish Energy Agency, and Mitsubishi UFJ Morgan Stanley Securities Co., LTd. and was the first biomass power plant to receive a PPA in Indonesia. It a good example of how landscape factors cause pressures on regimes, and support the growth of a niche - growing electricity demand on Bangka island put the existing electricity supply infrastructure under pressure, which resulted in blackouts, and motivated the exploration of alternative energy sources; which in turn were supported by international actors keen to support projects that contribute to a reduction in emissions.

Activities concerning rural electrification increased in this period, and were organised by a range of different actors. PLN aimed to expand on-grid and off-grid infrastructure, in addition to initiating the Super

Extra Energy Saving (SEHEN) program which provided both community and autonomous PV systems. Another government program, the Green PNPM-Rural, was launched in 2012 and aimed to alleviate poverty by supplying renewable electricity to rural communities. This program also predominantly focused on micro-hydro and solar PV (Sambodo, 2015). The majority of electrification programs were however initiated by foreign development agencies in collaboration with the DGNREEC and MEMR. The German Federal Ministry for Economic Cooperation and Development (BMZ), Ministry of Foreign Affairs of the Netherlands, Norwegian Ministry of Foreign Affairs, UKaid, Swiss Agency for Development Cooperation (SDC), and Swedish International Development Cooperation Agency (SIDA) commissioned the EnDev programs, which ran from 2005 till 2019. The programs were implemented by GIZ, Hivos, SNV (Dutch development organisation), the MEMR, and the DGNREEC. By 2017 258,000 people had gained access to electricity through the installation of 286 micro-hydropower plants, and 222 PV minigrids (Energising Development, 2017). In 2017 collaboration the BMZ commissioned another rural electrification program - 1,000 Islands – Renewable Energy for Electrification Programme. This project has been implemented by the DGNREEC in cooperation with GIZ and ran from 2017 till 2020. The goal of this programme is "to prove the technological and economic feasibility of renewable energy grid integration" and by doing so, encourage PLN to expand such renewable mini-grid projects across many more islands, making them part of their long-term plans (GIZ, 2017). The absence of biomass power from this range of electrification programs shows that the range of stakeholders involved in these program did not perceive biomass power to be a suitable or perhaps an optimal solution for rural electrification.

Transmission and distribution infrastructure expanded significantly in this period to facilitate the growth in electricity generation. Almost 14,000 km of transmission lines and 500 substations were added, reaching a total of 44,000 km and 1,571 by the end of 2016 (DGE, 2020). Over 300,000 km of distribution lines and almost 180,000 substations were added, reaching a total of 887,000 km and 433,511.

6.2.3 Network of Actors and Social Groups

The National Energy Council (DEN) was introduced by the 2007 Energy Law, marking the end of BAKOREN. DEN was led by the President (Chairman), Vice President (Vice Chairman), and the Minister of Energy sector. The main body of the council was composed of seven government officials from the energy industry selected by the President and eight stakeholders selected by the House of Representatives. The law stipulated that the eight stakeholders must contain two persons from scholar groups, industrial groups, and consumer groups, and one person from a technological group and one form an environmental group. The formation of the DEN strengthened the electricity sector network by incorporating the various actor groups in the decision-making process. The DEN is responsible for the formulation of long-term energy policies, as outlined in the National Energy Policy.

Between 2006 and 2016 the share of IPPs grew from 19.5% to 25.4% (Direktorat Jenderal Ketenagalistrikan, 2020). In the context of this increasing IPP presence in the regime the Indonesian Independent

Power Producers Association (APLSI) was founded in 2008. The aim of the APLSI was to connect IPPs and facilitate communication between IPPs, the Government, and any other related stakeholders.

The Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC) was founded in 2010 through Presidential Decree No. 24/2010. The role of the DGNREEC is to formulate and implement policy relating to new and renewable energy and energy conservation, in addition to supervising, evaluating, and managing developments in this area (MEMR, 2020a). Marquardt's expert interviews show that DGNREEC is widely regarded as the main driver for renewables in Indonesia (J. Marquardt, 2016). As solar, micro-hydro, biogas, and biomass power plants have been developed in rural settings that passively shield them from the selection pressures of centralised power generation, the DGNREEC has also become one of the main Indonesian actors driving rural electrification. The DGNREEC can play a key role in building professional capacity and experience related to renewable energy technologies within the regime - an inadequacy that has been characteristic of rural electrification programs throughout this period. Indeed, considering the scale of sustainable off-grid solutions necessary for achieving universal electricity access, a major concern is the severe lack of capacity and experience with such technologies within the regime, particularly with regard to PLN (Tharakan, 2015). Considering their expansive geographical coverage, access to government financing (public service obligation), and vast network of technical personnel, PLN could play a pivotal role in off-grid sustainable supply.

Finally, with regard to residential electricity consumers, the DGE reported an increase from 32.1 million households at the start of 2006 (DGE, 2009, p. 35), to 60.6 million households by the end of 2016 (DGE, 2020, p. 59).

6.2.4 Energy Justice

Availability

People deserve sufficient energy resources of high quality (suitable to meet their end uses)

In 2006, 56% of Indonesia's 226 million people had access to electricity (World Bank, 2020b; IEA, 2020b). Despite a significant increase in population to 262 million, the IEA estimates that in 2016, 91% of the population had access to electricity. In this time, per-capita electricity consumption rose from 500 kWh, to 900 kWh (IEA, 2020b). The number of people who gained access to electricity in this ten year period grew by almost 112 million people. Undoubtedly, massive gains have been achieved with respect to electricity access, however, by 2016 around 24 million people were still *deprived* of electricity access (distributional justice). Furthermore, many people who are considered to have access to electricity may only receive electricity for 2 hours each day, and suffer long periods of black outs - this is another case of distributional injustice, where the affected communities are *marginalised* by unreliable electricity supply (Sambodo and Novandra, 2019; Setyowati, 2020a).

Recognition injustices are also evident when considering electricity availability. Some islands where the majority of the population do not have electricity access are also considered electrified, and therefore are not considered in government electrification programs (Syahni and Danaparamita, 2017). For example, Siberut Island, where CPI developed three biomass gasification plants, was considered electrified and thus not included in the Government's Bright Indonesia program (Syahni and Danaparamita, 2017). These unelectrified households on Siberut have suffered recognition injustice in the form of *nonrecognition*.

Furthermore, well-intentioned rural electrification programs have led to distributional injustices in the form of *marginalisation* and *deprivation*. Sufficiency of supply refers to the minimum amount of electricity required for basic needs; defined as 50 - 100 kWh/person/year (AGECC, 2010), or 250 kWh/household/year in rural settings, and 500 kWh/household/year in urban settings (IEA, 2020a). This level is deemed sufficient for lighting, education, communication, and community services. Greater electricity supply can facilitate use of modern home appliances, or productivity gains through the use in agricultural machinery for example (Figure 3.3). Assessing outcomes from rural electrification programs against these definitions for electricity supply *sufficiency* reveals some shortcomings in government, PLN, and donor projects. PLN's Super Extra Energy Saving program (SEHEN) provided both community and autonomous PV systems to rural communities for a monthly subscription cost of Rp. 35,000. The SEHEN autonomous PV systems produce 26.4 kWh/year - well below the minimum electricity required for basic human needs (Sambodo, 2015). As this level of electricity supply is not sufficient for improving productivity and fostering development, communities that gain this access are at the same time *marginalised* (Figure 3.3). These electrification programs therefore fail to resolve the intragenerational inequities in electricity supply and consumption. Furthermore, project failures result in these newly electrified communities losing access - in the case of SEHEN, PLN decided to reclaim many of the solar PV units to recover some of its costs from the program that, after three years of operation, proved to be financially unsustainable (Sambodo, 2015). In this case, a well-intentioned rural electrification program led to extreme distributional injustices as households who recently gained access to electricity were later *deprived* of electricity access.

Affordability

All people, including the poor, should pay no more than 10% of their income for energy services

The government sets the electricity price for each consumer group (i.e. residential, building, etc.), and sub-group (e.g. residential consumer - low income 450 VA). Consumers pay fixed connection charges and variable charges based on their consumption. Most users are subject to a block tariff structure in which the electricity price (Rp/kWh) increases at predefined levels. Subsidy reforms have sought to align the electricity price with PLN's cost of generation for customers who are able to afford it - electricity has therefore remained highly subsidised for poor households. However, due to the highly politicised nature of electricity subsidies the Government was not been able to implement any significant reforms until 2012. After several reforms between 2012 and 2015 electricity prices for households with connections up to 900 VA remained unchanged, and by 2016 approximately 70% of households received subsidised electricity (P. J. Burke and Kurniawati, 2018; Global Subsidies Initiative, 2016). By 2016 poverty levels had decreased significantly to 5.2% at $ 1.90/day (World Bank, 2020b), which indicates that many of the households to have received electricity subsidies have not been poor (P. J. Burke and Kurniawati, 2018). However, published poverty headcount figures can give misleading impressions about the distribution of income levels within a country: choosing different values for the poverty line of the World Bank's Development Indicators Database one can see that in 2016, 28.6% of the population earned less than $ 3.20/day, and that 59.7% of the population earned less than $ 5.50/day (World Bank, 2020b). Indonesia's low electricity tariffs have been, and continue to be, *essential* for facilitating access to affordable electricity across the country.

Sovacool's definition of the *affordability* principle is that all people, even the poor, should pay no more than 10% of energy services. Analysing the 2016 National Social Economic Survey (Susenas), Sambodo and Novandra, 2019 show that approximately 53% of the 68.2 million households were energy poor in terms of expenditure. They found that the prevalence of expenditure-based energy poverty was much greater than consumption-based energy poverty - 17.9% of surveyed households consumed less the poverty threshold of 32.4 kWh/month. It is important to note that this definition of *energy* poverty encapsulates electricity and fuel consumption. Upon decomposition of energy poverty to electricity, generation, vehicle/transportation, and cooking, the authors found that the majority of energy expenditure was from fuel consumption for transportation. Indeed, considering expenditure on electricity alone, just 0.94% of households were electricity poor - a positive reflection of Indonesia's tariff system.

Due Process

Countries should respect due process and human rights in their production and use of energy

The expansion of coal-fired power generation in Indonesia has had enormous justice implications, particularly in rural communities in close proximity to coal mines and power plants. The lack of regulatory enforcement (at all levels of government) and the high prevalence of corruption has created an environment where regulatory processes can be either are completely ignored, or implemented merely symbolically (Fünfgeld, 2020). To acquire concessions for coal mining activities companies are obligated, under Mining Law No. 4/2009, to perform an environmental impact assessment (AMDAL), define development opportunities for the surrounding communities, and finance the rehabilitation of the land once mining activities have ceased. The law also stipulates requirements for health and safety, and waste treatment. Non-compliance with rules and regulations has led to injustices on an enormous scale. In 2016 the Indonesian Commission on Human Rights documented a range of human rights violations in

East Kalimantan relating to abandoned coal mining pits: the right to life, the right to have a good and healthy living environment, the right to justice, and child's right (The Republic of Indonesia National Human Rights Commission, 2016). The failure to restore the land at the some 500 abandoned coal mines in East Kalimantan, as per the regulations, has resulted in at least 25 deaths in recent years; mostly children who drowned in the abandoned open mining pits. Nationwide between 2014 and 2018 it is estimated that over 140 people have died in abandoned open-pit mines (Fünfgeld, 2020).

Transparency and Accountability

All people should have access to high quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making

On the project level, the examples above show that people have very limited access to high quality information about electricity generating infrastructure and its environmental impact (Fünfgeld, 2016; Setyowati, 2020b). From Fünfgeld's research on the Indonesian coal sector it is clear that despite requirements to inform affected communities about the impacts of projects and involve them in the AMDAL process, this seldom actually happens. Furthermore, if information is provided it is often presented in incomprehensible technical jargon so that the community do not have a clear understanding of the project's impacts. Further still, it is very unlikely that the AMDAL will provide impartial high quality information regarding the negative impacts of the project since the scientists performing the assessment are hired by the concession holders, who provide them with accommodation, transportation, and bribes (Nugraha, 2015; Fünfgeld, 2016). These revealing case studies show that at the project-level people often do not have access to high quality information about energy and the environment, nor do they have access to fair and transparent forms of energy decision-making.

Sustainability

Energy resources should be depleted with consideration for savings, community development, and precaution

In 2006 Indonesia had 4.4 billion barrels of proven oil reserves (BP, 2020) (Figure A.8). Oil production continued to fall from 1,018 thousand barrels per day in 2006, to 876 thousand barrels per day by 2016 (BP, 2020) (Figure A.9). Unable to implement sufficient measures to shift away from oil, domestic consumption continued to increase from 1,303 thousand barrels per day in 2006 to 1,572 thousand barrels per day by 2016. In this ten year period proven oil reserves were depleted by 25% - by 2016 these stood at 3.3 billion barrels. At 2016 production levels proven oil reserves will be fully depleted in around 10 years.

Production of natural gas in this period started at 76.3 billion m^3 in 2006, reached a peak of 87 billion m^3 in 2010, before declining to 75.1 billion m^3 by 2016 (Figure A.11). Consumption followed a similar trend, beginning at 37.1 billion m^3 in 2006, peaking at 44 billion m^3 in 2010, and stabilising a 44 billion m^3 by 2016 (Figure A.10). Proven natural gas reserves increased from 2.7 trillion m^3 in 2006 to 2.9 trillion m^3 in 2016. If proven reserves do not increase these could last for around 40 years at 2016 production levels.

Coal production at the end of 2005 was 152.7 Mt. By 2016 this had almost tripled to 456.2 Mt (BP, 2020). As the coal industry grew, the knowledge of reserves improved - by the end of 2016 Indonesia had 25,573 Mt proven coal reserves. In comparison to oil and natural gas, the figures for proven coal reserves has varied significantly over time, making it difficult to comment on the sustainability of production trends.

Intragenerational Equity

All people have a right to fairly access energy services

Significant disparities exist in the distribution of benefits and burdens of Indonesia's electricity regime. In terms of availability, the World Bank estimates that by 2018 1.5% of the population, or around 4 million people did not have access to electricity. However, when considering sufficiency and reliability, the number of people *deprived* of electricity supply, or *marginalised* to poor quality electricity will be significantly greater than 4 million. With respect to electrification ratios, significant spatial disparities have be observed, however these are much less pronounced now than when the ADB performed their report on universal electricity access in Indonesia back in 2015 (Tharakan, 2015). By 2019 electrification ratios in eastern Indonesia were still much lower than in western Indonesia; the minimum electrification ratio in eastern Indonesia was 85.8% on East Nusa Tenggara, while the minimum in western Indonesia was 94.6% in Kalteng, a difference of 8.8% (DGE, 2020). However the number of unelectrified households has historically been much greater in western Indonesia - in 2013 West Java alone had more unelectrified households than all eastern Indonesia (Tharakan, 2015). Regarding the cause for spatial disparities in electricity access, contrary to the narrative that electricity access is a result of regional wealth (GDP) or settlement patterns (population density), together these only account for one-fifth of the variation in electrification ratios between provinces (Tharakan, 2015). In general, the ADB found that regions with the lowest electrification ratios also had the highest generation costs; often characterised by dispersed rural users, which results in low demand density, and difficult terrain, which results in high transport costs for fuels and electricity. In their analysis the ADB concluded that although settlement patterns determine the least-cost method of electricity provision, electricity access is ultimately a reflection of government policy and commitment. The current electrification approach that is focused on expanding centralised generation fails to appropriately recognise the share of unelectrified households that are located in regions unsuitable for centralised power generation; thereby reinforcing the existing intragenerational equity.

Responsibility

All actors have a responsibility to protect the natural environment and minimize energy-related environmental threats

In the electricity regime, coal-based power generation is responsible for the greatest environmental damage, however, the exact impact is difficult to determine due to the high prevalence of corruption and opaque nature of the industry. Coal mining activities result in large areas of land clearances - in Kalimantan coal mining is the third largest cause of deforestation, behind palm oil and paper & pulp (Ottery, 2014). Between 2009 and 2011 Greenpeace estimate that coal mining accounted for a quarter of all deforestation in Kalimantan. This can be visualised by comparing the locations of coal mining permits (Figure 6.4) to geospatial deforestation data (Figure 6.5). The pink areas in Figure 6.5 show areas where tree canopy density has decreased by over 75% between 2001 and 2019.

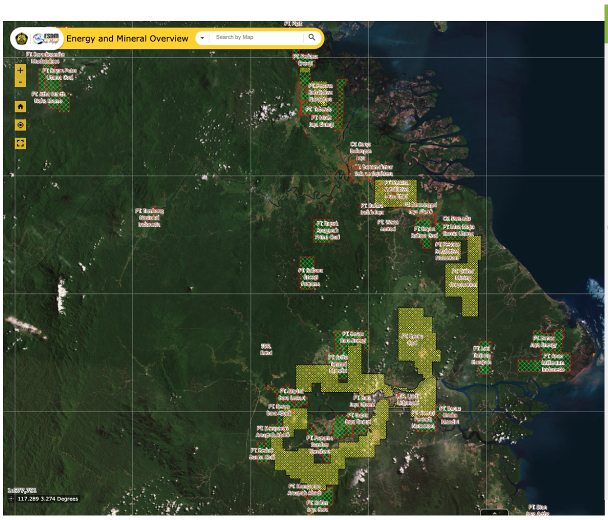


Figure 6.4: Location of coal mining permits (Source: MEMR, 2020b).

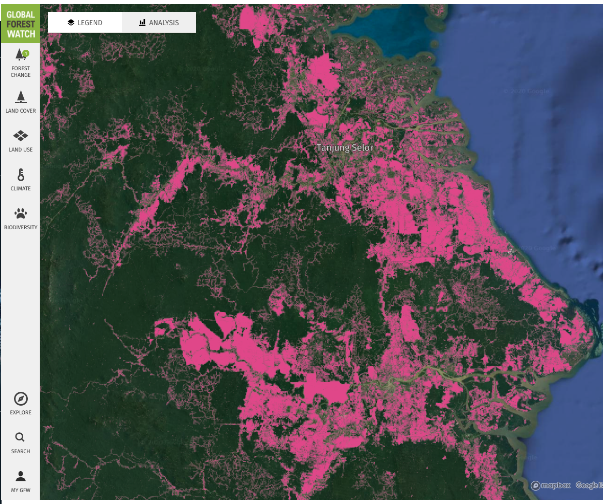


Figure 6.5: Tree cover loss over 75% canopy density 2001 - 2019 (Source: Global Forest Watch, 2020).

Figure 6.6 overlays this map with geospatial data on biodiversity hotspots, and the locations of endemic birds species - this provides further insight into how detrimental habitat loss in these areas are. The ape conservation charity Arcus Foundation estimates that by 2014 15% of orangutan habitat in Kalimantan overlaps with mining concessions, with major areas in East Kalimantan, where coal mining is very prevalent.

In addition to the direct environmental impacts of land clearing such as habitat fragmentation and land-use change emissions, projects that require extensive access roads through remote forests can have a devastating impact on the environment by facilitating hunting, illegal logging, land-clearing using fire, and land-grabbing for agriculture. A recent example is the 88 km road connecting PT Marga Bara Jaya's coal mines in Musi Rawas district to power plants in Musi Banyuasin district in Sumatra (Diana,

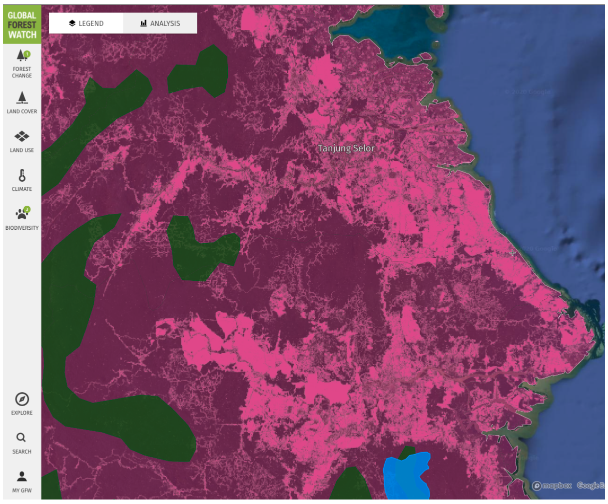


Figure 6.6: Tree-cover loss in relation to key biodiversity areas, hotspots, and endemic bird populations (Source: Global Forest Watch, 2020). The magenta background colour indicates that this entire area is a biodiversity hotspot. The habitats of endemic birds species are shown in green and blue.

2020). The road cuts through the Harapan forest; a lowland tropic rainforest in Sumatra which is home to some 1,350 species; 133 of which are classified as threatened, including the Sumatran tiger and Sumatran elephant (Diana, 2020). Environmental damage due to access roads is also one of the main concerns surrounding the further development of geothermal power, as much of the geothermal potential is located in remote regions. Since 2003 geothermal has been defined as a mining activity, and thus limited to development in Protection and Production Forest, and non-forest areas. Amongst other factors the complex compliance regulations associated with operating in forest areas has caused many delays and project cancellations (World Bank and PROFOR, 2019). However, with the revision of Geothermal Law No. 27/2003 to No. 21/2014 which sought to stimulate the sector, it is no longer classified as a mining activity and thus allowed to operate in previously restricted conservation areas. For each 100 MW power plant, around 10 km of access roads are required, leading to 30 hectares of land clearing which directly results in habitat fragmentation and emissions due to land-use change. However, due to the harmful activities facilitated by road access, such as hunting and illegal logging, the environmental impacts of projects extend to over 1000 hectares (World Bank and PROFOR, 2019). These activities are particularly concerning considering Indonesia's rich biodiversity (discussed below in Section 6.2.4).

Resistance

Energy injustices must be actively, deliberately opposed

Recent studies have brought attention to the growing resistance of marginalised communities who are continually threatened by large energy infrastructure projects (Fünfgeld, 2016; Fünfgeld, 2018). In the absence of official involvement in decision-making processes, marginalised communities have turned to

NGOs to support with protest activities such as blockages (Fünfgeld, 2016). The citizens who resist injustice are often criminalised and intimidated by a variety of public and private 'security firms', which in many cases has meant either thugs or paramilitary groups equipped with jeeps and modern weaponry (Fünfgeld, 2016; Fünfgeld, 2018). In spite of this, the anti-mining movement in Samarinda, East Kalimantan, managed to gain visibility on local and national media channels. This recognition by the media forced the local government to hear their concerns. This resulted in the coal company in question, CV Arjuna, agreeing to invest in infrastructure projects to improve local livelihoods. In this example, resistance by the marginalised local community resulted in some form of compensation (or promises thereof) for the negative impacts they face. However, the majority of rural communities that are impacted by these practices remain socially, economically, and politically marginalised and therefore have limited ability to articulate pressure on local and regional governments without the support of NGOs and the media.

Intersectionality

Expanding the idea of recognitional justice to encapsulate new and evolving identities in modern societies, as well as acknowledging how the realization of energy justice is linked to other forms of justice e.g. socio-economic, political and environmental

By 2011 the Research Centre for Biology of the Indonesian Institute of Sciences (LIPI) had recorded 31,746 species of vascular plants (UNFAO, 2011). In terms of fauna diversity, Indonesia is home to 12% of the world's mammals (515 species), 16% of the world's reptiles (781 species), 17% of the world's birds (1,592 species), 270 species of amphibians, and 35 primate species (UNFAO, 2011). Up to 3,305 of the animal species, and 29,375 vascular plants are endemic to Indonesia (UNFAO, 2011). The environmental damage caused by energy infrastructure described above therefore has an enormous impact on non-human life.

The land, water, and air emissions from coal mining activities and coal-based power generation seriously affect the lives and livelihoods of local communities. The stripping of topsoil from hills due to coal mining causes rapid runoff of rainwater into waterways, and has led to a drastic increase in the frequency and intensity of floods in areas like Samarinda in East Kalimantan where coal mining activities have boomed since the early 2000s (WWF Hob Global Initiative, 2012; Down to Earth, 2010). Major floods, like those in 2008 - 2009, seriously disrupted the economy, transportation, and affected local livelihoods (WWF Hob Global Initiative, 2012). These floods caused $ 9 million of damage, while the cost of flood mitigation measures is expected to reach $ 350 million (WWF Hob Global Initiative, 2012). Flooding has also led to drastic reductions in harvests; some farmers reported as much as an 80% reduction in sales (WWF Hob Global Initiative, 2012).

Furthermore, the negligent treatment of coal mine wastewater poses serious threats to non-human, and human life and risks contaminating local water sources which are used for drinking, bathing, and farming

(Ottery, 2014). A Greenpeace investigation of of coal mining sites in East Kalimantan found a high levels of toxic, acidic waste water: of the 29 samples, 22 had dangerously low pHs values below the legal limit of 6, while 18 were extremely acidic at below pH 4. Many of the samples were also reported to have high concentrations of heavy metals; including iron, manganese, nickel, and copper; which, in the worst case of iron, were 40 times greater than the legal limit. Another study found that soils surrounding coal mines in South Kalimantan were contaminated with polycyclic aromatic hydrocarbons (PAHs) - short-term exposure to PAHs causes skin irritation and inflammation, while long-term exposure can result in "decreased immune function, cataracts, kidney and liver damage (e.g. jaundice), breathing problems, asthma-like symptoms, and lung function abnormalities", in addition to increased risk of skin, lung, bladder, and gastrointestinal cancers (Abdel-Shafy and Mansour, 2016, p. 115).

6.3 Niche 2006 - 2016

The introduction of a fixed FiT for biomass power plants in 2012 was the first regime regulation directly related to biomass power generation. Although it was not specific to the gasification niche this can be considered the first 'soft' shielding measure originating from within the regime as it provided a long term financial incentive for biomass power generation. The main niche shielding, however, came from multi-lateral and bi-lateral aid agencies.

6.3.1 Network Formation

Composition

During this period six main actor groups have conducted projects in an isolated manner. The first actor group is comprised of Tokyo University of Agriculture and Technology (TUAT), Yayasan Dian Desa (YDD) - a small Indonesian NGO that has been working on rural development projects since 1968, the Asian People's Exchange (APEX) - a Japanese NGO with a long history of implementing development projects in Indonesia, and BPPT - the Indonesian Agency for the Assessment and Application of Technology. This actor group constructed their first 25 kW biomass gasification plant in 2005 in Jogjakarta. Following this successful demonstration project the group were able to attract the support of New Energy and Industrial Technology Development Organization (NEDO) - Japan's largest public management organization - who funded a larger 135 kW pilot plant in 2008. The composition of this actor group changed slightly in 2014 with the implementation of the Japanese government's SATREPS project which supports research projects targeting global issues in developing countries. Through the SATREPS project the Japanese Science and Technology Agency (JST) and Japanese International Co-operation Agency (JICA) supported Gunma University (Japan) and BPPT in the development of a low-cost fluidized-bed biomass gasification plant for methanol production.

The second actor group is comprised of Trillion International PTE. Ltd. (Trillion) and the agribusinesses with which they partner such as Astra Agro, Kencana, and Sinarmas. Trillion is a manufacturer of gasifier systems that have a strong track record of operating in the South East Asian context, particularly in Myanmar. Trillion's international operations allow them to accumulate experience and learning on a large scale in a variety of different contexts. Trillion was the first international commercial gasifier manufacturer to enter the market in Indonesia - their entrance marks an improvement to the overall biomass gasification niche actor network.

The third actor group worked on a biomass gasification project in Munduk, Bali, and consisted of the Indonesia Institute for Energy Economics (IIEE), PT Gasifikasi Prima Energi (GPE), Bank Negara Indonesia (BNI), USAID, INSIGHT, and the Wisnu foundation. Firstly, the IIEE is an NGO founded in 1995 with the objective of supporting responsible development and utilisation of energy resources in Indonesia. Although the Munduk project was the IIEE's first biomass gasification project it has significant experience with energy policy analysis and facilitating high level events such as the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) Workshop on SDG7 Implementation Roadmap to Achieve the 2030 Agenda for Sustainable Development. Although GPE were not mentioned in the IIEE project report it appears from GPE publications that they contributed technical knowledge in the implementation of the project (BIOENERGI, 2014; Fatimah et al., 2014). The IIEE chose to partner with the gasifier manufacturer Trillion, which by 2013 already had several years of experience supplying gasifier systems to agribusinesses in Indonesia - mainly palm oil plantations. The project was financially supported by BNI and the Indonesia Clean Energy Development program (ICED) 2011 - 2020; a technical assistance program funded by USAID which supports not only project developers and PLN, but also advises on energy planning and policy reform to national and local governments, and assists various financiers with evaluating proposals. The final two actors are INSIGHT - a self-empowerment organization, and the Wisnu foundation - environmental management and community empowerment.

The fourth actor group is centred around Clean Power Indonesia (CPI), which was founded in 2012 and aims to empower rural communities through electrification. CPI initiates and develops biomass power generation projects that are managed for and by community users. CPI also acts as a facilitator and partner for organisations, communities, and government institutions working in this field. CPI initially partnered with General Electric (GE), and together were invited by the Bali regional government to build a waste-to-energy power plant in Nusa Dua. In this project they also collaborated with PLN who (at least initially) agreed to purchase the electricity from the plant. This engagement with PLN is significant for the niche as until this point PLN did not have any interaction with biomass gasification projects - all projects were either small-scale demonstration projects or rural electrification projects that operated in regions outwith PLN's network.

The fifth actor group was formed as part of the Sumba Iconic Island project and initially involved the DGNREEC, Ankur Scientific Energy Technologies Pvt. Ltd. (ASCENT), MoEF, PT. Pasadena Engineering Indonesia (contractor), Hivos, GIZ, PT. Usaha Tani Lestari (feedstock supplier), and the local government. The actor group went through a number of changes in response to challenges regarding the project implementation. The project initially planned to hand over responsibilities for the operation and maintenance of the plant to the local community, however it was determined that the planned training failed to adequately prepare the local people to operate, maintain, and manage the power plant. The developers then requested that PLN take on these responsibilities, who subcontracted this to their subsidiary Indonesia Power, and by 2016 an MOU had been signed. As with the previous actor group, this involvement of PLN (through Indonesia Power) is very important as they have an expansive network of technical personnel (albeit with very limited experience with biomass gasification as of yet).

The sixth actor group revolves around ITB, which has been involved in the biomass gasification niche since the late 1970s. In this period they collaborated with central government ministries (DGNREEC and MEMR), funding institutions, local government and village management, steel workshops and manufacturers, and transportation actors (Interviewee 3 - Researcher, 2020).

Although the nature of project collaboration, in which demonstration projects were sponsored by domestic and international donors, in comparison to the previous transition period and the first half of this transition period the network has been strengthened with the addition of two Indonesian project development/implementation actors - IIEE/GPE and CPI. The overall niche network also benefited from the introduction of GE and Trillion in 2012 - two experienced manufacturers of gasification systems. These international actors, who accumulate experiences and learning on a much greater scale than domestic actors, add a lot of value to the overall composition of the Indonesian biomass gasification niche. By the end of this transition period a wide range of actors played key roles within the actor groups described above - research institutions (ITB, whose activities were restarted with support from the DGNREEC in 2011 - 2014), NGOs (APEX/YDD/IIEE), private companies (CPI/GPE/Trillion/GE), the Government (through the DGNREEC), and finally the state-owned electricity utility PLN.

Alignment

There was significant experimentation and variation between actor groups with respect to the purpose of projects, end-users, equipment, and feedstocks. With respect to the purpose and end-users three of the six actor groups - ITB, DGNREEC, and GPE - sought to improve access to electricity in rural communities, increase energy security, and foster rural development. Of the other three actor groups, the purpose of APEX's projects in 2005 and 2008 were to demonstrate the use of clay catalyst for biomass gasification, and foster rural development; the purpose of CPI's project in 2012 was to demonstrate the commercial viability of MSW gasification; while the final group of actors used Trillion's gasifier systems to reduce operational costs and increase energy security. With the implementation of the SATREPS project in 2014 APEX's purpose shifted to low-cost methanol production, marking a divergence from the other actor groups in this period which focused on electricity generation.

Four actor groups chose agro-industry waste as feedstocks - ITB used corn cobs and oil palm fronds, APEX used waste from palm oil processing plants, the IIEE used rice husks, and the final group utilised a wide range of agro-industry waste. The other two actor groups, CPI and DGNREEC, utilised MSW and Calliandra wood chips, respectively. Although CPI's main ambition has been to demonstrate the use suitability of bamboo feedstocks for power production, they were contracted by PLN and the regional government to utilise MSW in response to growing concerns over poor waste management. The DGNREEC actor group, which is a part of the Sumba Iconic Island project, built their power plant within a land concession which could be used to grow the Calliandra feedstock. This project was the only project in this period not to utilise waste biomass. Despite the seemingly integrated nature of the power plant and feedstock production, this project had to purchase feedstock from the concession holders PT. Usaha Tani Lestari. With the exception of the agro-industry actors, all other projects had to purchase feedstock from producers. In sum, there has been a significant amount of experimentation between the actor groups in this period.

Projects have been implemented in an ad-hoc manner as there has been no master plan within the Indonesian actors on how to develop and scale-up this technology (Interviewee 3 - Researcher, 2020; Interviewee 2 - Researcher, 2020; Interviewee 4 - Researcher and Industrial User, 2020; Interviewee 5 - International Project Facilitator, 2020; Interviewee 8 - Government, 2020). Furthermore, there has been very little interaction between the different actor groups in this period (Interviewee 3 - Researcher, 2020; Interviewee 2 - Researcher, 2020; Interviewee 5 - International Project Facilitator, 2020). The absence of cross-project communication means that experiences were not shared between actor groups, and that the lessons learned from each project were not used to further the development of the niche. The lack of interaction across the different actor groups is therefore a factor that to some extent inhibits the growth the niche. Considering the need for greater coordination of niche activities it is clear that this is a role that is currently not fulfilled by any niche actor. The DGNREEC, in particular the Directorate of Bioenergy within the DGNREEC, appears like the most suitable actor to take on this responsibility, however there remains questions of priorities, capacity, etc. This will be discussed further in Chapter 8.

6.3.2 Learning Processes

Technical and infrastructure developments

YDD have experimented with fluidized bed gasifiers for electricity production, and also for methanol production. Their initial project in 2005 had a capacity of 25 kW. Experiences from this small-scale demonstration were used to scale-up the system to 135 kW in 2008.

The IIEE and CPI have both used down-draft gasifiers from foreign manufacturers: the IIEE from Trillion, and CPI from GE. In their Munduk project the main technical learning for IIEE was that impurities in the feedstock - rice grains mixed with the husk feedstock - can cause the reactor to clot and choke. Trillion were able to draw on a much greater number of experiences in several countries, including

Indonesia, with different locations, clients, and end uses - from rural electrification, to saw mills and palm oil plantations. Over the period they used experiences to refine their design and experiment with new units - they developed an automated charging and discharging system, several new dual-fuel generators, produced higher capacity systems, combined the system with a MSW pelletizing unit designed by STT-PLN, and recently developed a gas engine. The automatic charging and discharging system was one of the recommendations of the IIEE project based on their experience with operators who were reluctant to load new feedstock every two hours. At the time of the Munduk project Trillion were trialling a new discharging and charging system in Malaysia. The addition of a temperature sensor safety control system to their gasifier designs was a result of experiences of sub-optimal operation where problems with excessive temperature were ignored by operators instead of resolved, leading to equipment malfunction and damage (Interviewee 10 - Manufacturer, 2020).

In this period ITB also implemented several small-scale projects where they handled the system design, manufacturing, installation, training, monitoring, and setting up local science and technical agents (researchers from university or workshops) (Interviewee 3 - Researcher, 2020). In 2008 they installed a 65 kW gasifier in Banjarmasin (South Kalimantan), which utilised corn cobs and supplied electricity to a rural community (Interviewee 3 - Researcher, 2020). Between 2011 - 2014 they installed five 100 kW gasifiers in rural communities in Riau Province.

The Indonesian intellectual property database shows that in 2012 there was a significant increase in the number of patents applied for relating to biomass gasification (Figure 6.7). These patent applications have originated from a range of research institutions, universities, corporations and limited companies from eleven countries (Figure A.12, Appendix A). However, there is no readily available information regarding the activities of the majority of these patent holders.

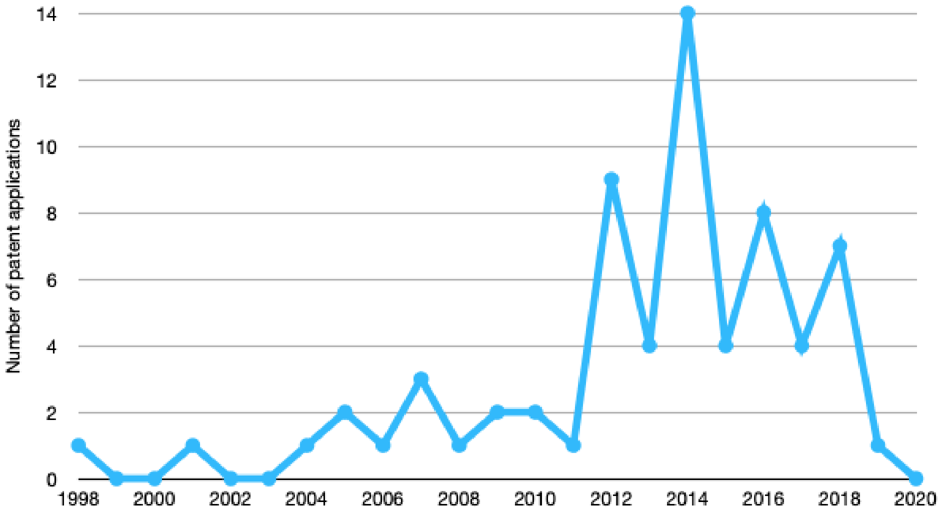


Figure 6.7: History of patent applications relating to biomass gasification in the Indonesian Intellectual Property Database (Source: author).

User Experience

IIEE's project in Munduk faced a variety of operational problems. Firstly, the risk husk feedstock produced more tars than expected, leading to equipment fouling and increased maintenance activities. The operation of the plant proved to be very challenging and work-intensive which made operators reluctant to operate the plant (Fatimah et al., 2014). Due to a lack of technical background in the community, only a few members were able to operate the plant - this is a problem as the plant is designed to operate 24 hours. The limited local capacity to operate the plant limited the number of hours of operation, which in turn severely impacts the economics of the system, and the societal and environmental benefits (below). This touches on a core challenge of implementing biomass gasification projects in rural areas where there is a very limited number of people with the technical competencies required to operate these complex and work-intensive power plants (Interviewee 5 - International Project Facilitator, 2020; Interviewee 9 - Independent Expert, 2020). The people persevered with the operation for the first three years of the project when grid supply was not available, however, the expansion of PLN's grid electricity supply in the third year of operation was a major challenge for the project as people much prefer not to work to generate their electricity (Fatimah et al., 2014). IIEE's experience with operators was also shared DGNREEC on the Sumba project - after several unsuccessful attempts were made to train local people the DGNREEC asked the local PLN office to operate the power plant (Interviewee 8 - Government, 2020). Furthermore it is common that people who do gain such competencies often move to the cities to find jobs, even with the possibility of working at such a power plant as the pay is relatively low compared to alternative work in cities (Interviewee 5 - International Project Facilitator, 2020).

Trillion's learning about user experience was very similar. The vast majority of problems experienced in practice were not due to technical problem from the system design, but rather poor operational practice. In contrast with IIEE who relied on local people to operate the plant, Trillion's operators were typically plantation workers. Although they had more technical background due to their profession, their motivation to operate the plant was low. As the gasifiers, which were typically used for village electricity, were operated at night and in the mornings they would operate for around 8 hours each day instead of 24 hours. The implication of this operating schedule is that the gasifier is in a constant state of start-up and shutdown - the most challenging phases of operation when operators must be diligent to ensure good operating conditions are reached. During start-up the emissions are high due to the low temperature in the gasifier - this means that the gas filters need to be changed more often - increasing the work for the operators. Correct operation of the gasifier is perceived as too much work so there is a high turnover of operators, especially if the operators are unpaid (Interviewee 10 - Manufacturer, 2020). The implication of this is that the few operators that were trained sufficient at the start of the project have to handover their knowledge to the new operators - a process that has proved very ineffective and often leads to insufficient knowledge of the system. The gasification process is more complex than the standard diesel systems that typical workers have experience with. The lack of familiarity and understanding of the process results in operators cutting corners. For example, instead of investigating and resolving the cause of excessive temperature operators have continued to run the plant - a decision which has resulted filter malfunctioning and the flow of tar into the generator, causing equipment fouling (Interviewee 10 - Manufacturer, 2020). To protect equipment from operator negligence to excessive temperatures Trillion introduced temperature safety control systems to all their gasifier systems - the IIEE actor group later benefited from this learning as they used Trillion's TG70 gasifier system in Munduk. This is an illustrative example of how an actor has changed the design of the system due to learning about user experience. However, even with this temperature safety measure in place they experienced problems as some operators would disconnect the temperature sensor so that they could continue to operate without troubleshooting (Interviewee 10 - Manufacturer, 2020).

Policy and Regulatory Environment

GE's feasibility study for a 1 MW biomass gasification plant on Sumba Island was performed in Umbuwangu, Southern Sumba. The study indicated that the project is only economically feasible if the opportunity cost of replacing the existing diesel generators is included in the analysis. If this is considered, the project reached 20% IRR, and has a payback period of 10 years, however, if this is not, the NPV is zero (Rifa et al., 2012). The LCOE of the biomass gasification system $ 0.112/kWh, compared to $ 0.36/kWh for the existing diesel generators. The technology (engineering, procurement, and construction) and infrastructure capital costs of the system were the main costs influencing the LCOE. Besides the capital investment, operational costs had a significant impact on the project's economic performance. Regardless, their study showed that the tariff available in 2012 for biomass power plants was too low to incentivise commercial projects (Rifa et al., 2012).

Several regulatory changes in this period saw changes in the land rights and tenure management. Recent land reform in Indonesia has two main components: (1) Agrarian Reform, and (2) Social Forestry. Firstly, Presidential Regulation 86/2018 on Agrarian Reform aims to redirect the benefits of natural resources to local communities by rectifying the disparity in land control (World Bank, 2019). This regulation sees the redistribution of 4.1 million ha from the state, to landless communities. Social Forestry allows communities to access and manage state forest lands - the programme targets 12.7 million hectares by 2019 (Resosudarmo et al., 2019). The Social Forestry Program, that was introduced in 2015 under the Government's poverty alleviation program, contains six schemes: 1) community forestry, 2) village forestry, 3) community plantation forests, 4) customary forestry, 5) forestry partnership, and 6) community forestry on titled land (World Bank, 2019). Prior to these reforms it was difficult for niche actors to implement projects with feedstock cultivation as the concession holders were typically large corporations who were mainly focused on lucrative export markets (Interviewee 1a and Interviewee 1b - Local Project Developers, 2020). For example, a biomass gasification plant utilising wood chips will not be economically viable if it purchases the feedstock at the same rate as the export price for wood chips which is around $ 150/tonne (Interviewee 1a and Interviewee 1b - Local Project Developers, 2020). These changes in regulations, which (1) redistributes land to communities, and (2) allows communities to access, use, and manage state forests, opens the possibility for communities to come together with sufficient land necessary to cultivate feedstock for biomass gasification projects (Interviewee 1a and Interviewee 1b - Local Project Developers, 2020).

Biomass Potential

Each actor/actor group learned about biomass potential in isolation. For each project actors performed surveys of available biomass sources - mainly by combining publicly accessible data from BPS on the production of various agricultural products, with data on the production of waste from these products which is widely available in research papers. The size of these surveys varied between project groups - for the IIEE project in Munduk actors already intended on using rice husks based on prior knowledge that there were nearby rice mills. Their survey was therefore relatively light and confirmed the locations of rice mills and available rice husks (Fatimah et al., 2014). The investigation of biomass feedstocks on the Sumba Iconic Island projects was much more thorough by comparison - this is due to the nature of the project, which had a broader objective to supply 100% of Sumba's energy demand with renewables. The feasibility study for this project investigated the potential of several different biomass sources available on Sumba island: coconut shell, candle nut shell, corn cobs, rice husks, cashew waste, and bamboo (Frederiks, 2013). The combined analysis of feedstock cost led to several conclusions about the feasibility of biomass feedstocks in different regions of Sumba.

Business Models

There was some variation in business models between the actor groups. The main learning for actors regarding business models in this period was about the challenges of not owning the feedstock. In IIEE's Munduk project experienced feedstock insecurity due to an increasing market for rice husks - that were also used in the brick industry and for chicken farming. After three years the price of rice husks increased by 1.5 - 2.5 times from Rp. 6,000 - 10,000/sack to Rp. 9,000 - 25,000/sack (Fatimah et al., 2014). On Sumba Island the DGNREEC also experienced problems with feedstock supply - due to the three year delay between the signing of the MOU with the feedstock supplier to the projects operation date the feedstock supplier requested a higher price which would account for inflation and increased wages (Interviewee 8 - Government, 2020). However, this was considered unacceptable to PLN, who had recently agreed to operate the power plant. A major learning point for actors in this period was that feedstock security in terms of quantity, quality, and price is a major challenge for projects that do not own the feedstock supply.

6.3.3 Voicing and Shaping Expectations

Trillion's successful projects with rice husk gasification in Myanmar created positive expectations of their technology for use this feedstock. The IIEE's project in Munduk, which planned to make use of rice husk waste from nearby rice mills, chose to use Trillion's gasifier for the project - a clear example of how learning processes (in Myanmar), shaped expectations (of the IIEE actor group), and resulted in additional learning processes (Munduk project). The nature of IIEE's project in Munduk, in which the local community were trained to operate the small-scale gasifier is also an indication of the actors' expectation of the technology. The variation between projects thus to some extent illustrates the different expectations between actor groups. For example, in contrast to the Munduk project, the pre-feasibility study on Sumba shaped actor expectations that:

"Gasification is probably only feasible on a large scale (grid connected), because of the complexity of the technology and the related technical capacity of the plant operators. Scale will be dependent on supply possibilities of appropriate feedstocks (coconut shell, candle nut shell, corn cobs)" (Frederiks, 2013, p. 6).

The scale (small-scale vs large-scale), and the project model (employment of local community) are two key differences between the expectations of the IIEE and DGNREEC actor groups.

A workshop co-organised by BAPPENAS and CIFOR at the end of this period (May 2016) allowed a diverse group of stakeholders to share their experiences and perceptions on the challenges and opportunities of bioenergy development in Indonesia (Pirard, Bär, Dermawan, et al., 2016). Several key themes emerged: 1) actor's agreed that there is significant potential for bioenergy in Indonesia, 2) technologies and data management should be improved, 3) wood-based power generation still lacks a proof of concept, 4) integrated plantations seem necessary to expansion of wood-based power generation, and finally 5) the Government and state-owned enterprises should take a bigger role in bioenergy development. In terms of data management, operational maps would aid planning and investments by helping to identify suitable sites, considering current land use, slops, access, and soil fertility. One of the barriers identified was uncertainty about land tenure - a problem that Indonesia's One Map (launched in 2018) addresses by providing harmonized information on land tenure, land uses, and licenses (Mufti, 2020). The next highlights that there is yet to be a proof of concept for wood-based power generation - no commercial wood-based power plants are operational in Indonesia (this model differs from captive and excess power generation from agro-industries utilising available residues). Participants recognised that small-scale gasifiers are available, and suitable for rural off-grid setting where electricity demand is low. However, experiences from Sri Lanka and India shape expectations that operating and maintaining small-scale gasifiers will be challenging, and that the business model can struggle to compete with alternatives like diesel, solar, and micro-hydro, due to high capital and operational costs (Pirard, Bär, Dermawan, et al., 2016). These expectations are widely held regarding options for rural electrification and is evident in the preference of solar and micro-hydro in all of the major rural electrification programs (Sambodo, 2015; GIZ, 2017). In the context of insecure land tenures and local claims, long licensing processes, lack of investment, and competition for land use, outgrower schemes that rely on many land owners to supply biomass feedstock to the power plant were perceived to be a more viable option than integrated plantations. Such models face different challenges; especially regarding long-term security of supply that involves coordinating many smallholders. With this workshop event, the experiences of actors were shared and the expectations of network were harmonized to some extent.

Second-Order Learning

There were no examples of second-order learning identified in this period.

6.3.4 Energy Justice

Availability

People deserve sufficient energy resources of high quality (suitable to meet their end uses)

The IIEE Munduk project supplied 85 households, 1 primary school, and 1 temple with 200 W/day each (Fatimah et al., 2014). The gasifier would operate for 6 hr/day, thus supplying each household with 1200 Wh/day. Assuming that the gasifier would operate for around 80% of the year this would equate to around 350 kWh/household/year. In a four person household this would still be in the range for electricity sufficient to meet one's basic needs (88 kWh/person/year), while in a two person household this would also be sufficient for more productive uses (175 kWh/person/year). Assessment of supply sufficiency, measured in kWh/person/year, is dependent on the amount of hours the gasifier operates - long periods of inactivity can change the outcome of the project from sufficient to insufficient. Due to lack of available data on actual operational hours it is not possible to comment on this over the duration of the project. Nonetheless, this project has greatly contributed to the availability of energy resources to this community which previously did not have access to electricity. No data is available for the electricity supply of either the agribusinesses using Trillion's gasifiers, or from ITB's projects in Riau 2011 - 2014.

Affordability

All people, including the poor, should pay no more than 10% of their income for energy services

Of the projects that reached operation in this period - IIEE Munduk, agribusinesses/Trillion, and ITB Riau - there is no available data which details the electricity price that the consumer paid.

Transparency and Accountability

All people should have access to high quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making

Unlike larger commercial energy projects, community engagement was key to the Munduk project - the project required local people to help build the civil constructions, and attend training sessions in order to be able to able to operate the gasifier. IIEE partnered with the Wisnu Foundation to manage local community engagement throughout the project. The approach consisted of stakeholder mapping and analysis, stakeholder consultation, and forming a core team of local people. Community consultation ensured that that people had access to high quality information about the project and were involved in the decision-making process.

Intragenerational Equity

All people have a right to fairly access energy services

The IIEE actor group supplied electricity to 85 households, 1 primary school, and one temple in Munduk that previously had no access to electricity. Many of the agribusinesses that operate with Trillion gasifiers supply electricity to the local community (Interviewee 10 - Manufacturer, 2020), however, no exact figures are available for this, or information on their operational status. This is also the case for ITB's village electricity gasifiers in Riau province that were installed between 2011 and 2014 - monitoring of these gasifier was funded by the DGNREEC and lasted for three months.

Responsibility

All actors have a responsibility to protect the natural environment and minimize energy-related environmental threats

ITB and Trillion have both opted to use water scrubbers for gas cleaning (Susanto, 2018; Fatimah et al., 2014). The caveat to improved separation is that a wastewater stream is produced, containing the impurities removed from the producer gas. In earlier projects such as the rice husk gasifier in Haurgeulis, Indramayu Regency in 2005, ITB found that the wastewater streams had high phenol content - causing the death of a catfish in less than 30 minutes (Susanto, 2018). In comparison, designs published in this period show the inclusion of wastewater treatment units - a clear indication of ITB's measures implemented to minimise energy-related environmental threats (Susanto, 2018).

As a manufacturer of gasifiers, Trillion does not benefit from the support of the Indonesian government, or foreign governments. One of the main barriers to gasifiers, especially in the commercial environment, is the upfront capital cost of the system. Minimising the system cost is therefore of paramount importance to actors like Trillion who sell gasifiers in developing countries. Once the water from the pool has become saturated with impurities it is discharged onto the surrounding land. In these cases, the environmental threats have not been minimised and some harm to the environment is expected. However, it is important to consider the possibility that with such a wastewater treatment process the system may become prohibitively expensive, thus motivating the customer to opt for a small-scale diesel power plant instead - an option that is far more damaging to the environment than the biomass gasification alternative, and still with no guarantee of that the wastewater is treated. Although Trillion do not implement wastewater treatment into their current gasifier models marketed in Indonesia, this should be viewed as a result of the context in which they operate - strong pressures to minimise costs, supplying to customers who are motivated by cost savings from the substitution of diesel, and not climate change or the environment.

Intersectionality

Expanding the idea of recognitional justice to encapsulate new and evolving identities in modern societies, as well as acknowledging how the realization of energy justice is linked to other forms of justice e.g. socio-economic, political and environmental

IIEE's Munduk project sought to supply electricity to around 85 households that previously had no access and had relied on highly polluting and expensive kerosene lamps for light. While operational, this project therefore contributed to improved health and socio-economic justice in Munduk. The project further contributed to socio-economic justice by training local residents to operate and manage the power plant.

Considering the richness and significance of Indonesia's biodiversity, a key risk for the biomass gasification niche is that projects contribute to biodiversity loss through land clearing for tree plantations (Sections 6.2.4 and 6.2.4). Unlike other projects in this period the Sumba project opted for an integrated plantation to mitigate the risk of poor feedstock security. The implication of this is that the project supports the clearance of forest for feedstock cultivation.

6.4 Summary

Niche projects early in this period were **actively shielded** by the Japanese government through bilateral development cooperation. Around 2010 additional niche projects were implemented, benefiting from the **active shielding** provided by both the Indonesian government and various foreign governments like the Netherlands, Germany, and the US. All projects were implemented in rural areas where they also benefited from **passive shielding**. Donor activities in this period were largely motivated by the intensifying landscape pressure to implement climate change mitigation projects - at the heart of which is **sustainability**, **intergenerational equity**, **responsibility**, and the **intersection** with health justice. Projects were also oriented to the landscape pressure to increase energy access in rural areas and facilitate economic development - **availability** and **intragenerational equity**. The formation of the DGNREEC in 2010, the introduction of FiTs for small-scale bioenergy projects in 2012, and the setting of the renewable energy target in 2014 were all key developments at the regime level that contributed positively to niche development.

The niche network grew significantly over this period, attracting a wide variety of actors, from government ministries, to international donors, international research institutes, NGOs, manufacturers, and PLN. These actors implemented a range of projects which facilitated different dimensions of learning, from ITBs research on viable business models, to IIEE's learning about suitable project models. However, the rich actor network and the range of learning processes undertaken did not greatly enhance niche development as learning was not shared between project actor groups. The challenges experienced and lack of successful implementation reshaped the expectations of many actors in this period.

7 2017 - 2020: Increasing Niche Momentum

7.1 Landscape 2017 - 2020

International oil prices dropped from their peak of \$ 109.5 per barrel in 2012, to just \$ 41.5 per barrel in 2020 (Statistica, 2020). This drop in oil prices decreased the pressure on the Government and oil consuming businesses to shift away from oil. This has had a number of impacts at the regime and niche levels (discussed below).

COVID-19 is the latest shock event to impact Indonesia. The World Bank estimates that COVID-19 will push 5.5 - 8 million Indonesians into poverty (World Bank and Bank Dunia, 2020). The majority of the new poor will come from the traditional services and agriculture sectors, and from rural areas (Figures 7.1 and 7.2. One of the key opportunities to arise from this crisis is to accelerate just low carbon rural development (GARCILAZO et al., 2020). In an attempt to mitigate rebound emissions from the economic recovery and foster low carbon development, the ADB have pledged to doubled their annual loan commitments to Indonesia; which have amounted to between \$ 1 billion and \$ 2 billion the previous years; most of which are for energy-related infrastructure projects (Harsono, 2020). However since early 2020 the Indonesian government has invested just \$ 0.24 billion in clean energy, compared to \$6.72 billion investment in fossil fuels (Energy Policy Tracker, 2020). Changes at the landscape level in the coming months will have a significant effect on the Indonesia's economic recovery, and the resulting poverty and emissions levels.

The US-China trade war is another landscape factor that is likely to have a significant effect on the Indonesian energy sector. The Phase One Deal requires China to increase imports of US energy products, manufacturing, agriculture, and services (World Bank and Bank Dunia, 2020).

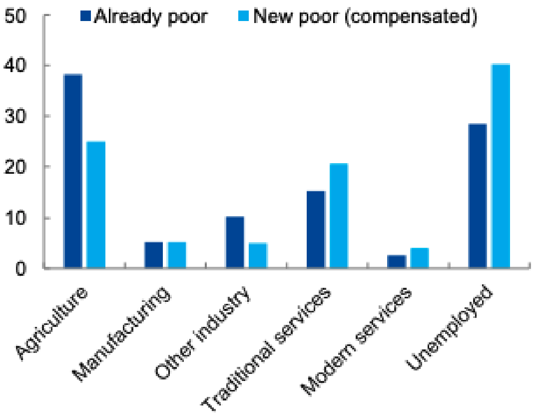


Figure 7.1: New poor by employment sector (Source: World Bank and Bank Dunia, 2020).

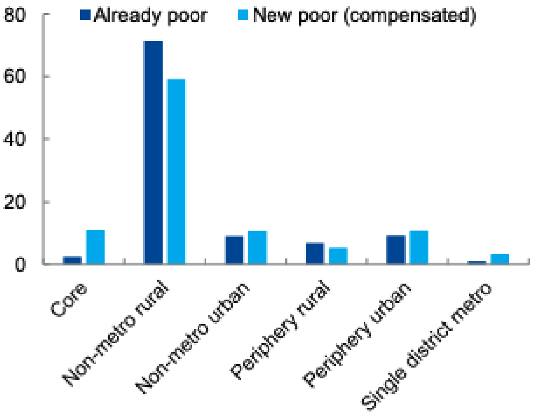


Figure 7.2: New poor by living area (Source: World Bank and Bank Dunia, 2020).

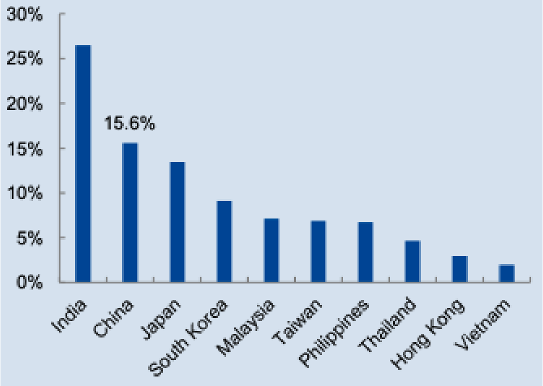


Figure 7.3: Share of Indonesia's coal exports by country 2014 - 2018 (Source: World Bank and Bank Dunia, 2020).

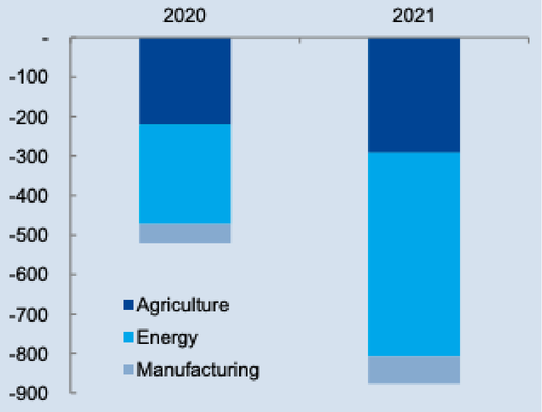


Figure 7.4: Anticipated losses from US-China trade deal in US dollars (Source: World Bank and Bank Dunia, 2020).

Between 2014 and 2018 China imported 15.3% of its coal and 9.2% of its LNG from Indonesia, compared to just 1.6% coal and 2.6% LNG from the US (World Bank and Bank Dunia, 2020). Indonesia is likely to lose out on diverted Chinese energy imports (Figure 7.4). Lower coal exports risk increased domestic consumption, particularly in the electricity sector. This landscape development therefore poses a serious risk for Indonesia's low carbon development plans.

7.2 Regime 2017 - 2020

7.2.1 Rules

Formal Rules - Strategy

In 2014 the Government launched the ENERGI Berkeadilan (fair energy) programme which aims to provide energy (*availability*), at affordable prices (*affordability*), for all Indonesian people equitably and evenly (*intragenerational equity*) (ESDM, 2019). Although efforts to improve electricity access and accelerate rural development predate the Widodo administration, since 2014 the Government has been more explicit in their communication of their energy justice vision. However, **the Government's current vision of energy justice focuses only on the *availability* and *affordability* of energy and is very much limited to distributional justice.**

In 2017 the Government announced plans for hundreds of new diesel-powered generators across Indonesia. The choice of diesel-powered generators is perhaps in part due to the falling international oil prices, which decreased the Government's financial burden of oil imports and subsidies. It is also very much inline with previous government-led rural electrification efforts - this announcement is an indication that the Government's perception is still that diesel-powered generators are the best solution for rural electrification. This plan is in spite of numerous successful rural electrification programs throughout the period such as the Sumba Iconic Island program that used a combination of solar and micro-hydro power to not only provide communities on Sumba with electricity for the first time, but also make them largely independent of fuel imports.

Just three years later in 2020, under increasing pressure to achieve the 23% renewables target by 2025, the MEMR announced plans to convert diesel power plants older than 15 years, and coal and steam gas plants older than 20 years, to renewables (Wicaksono, 2020). The list of power plants considered for replacement is comprised of 2,246 diesel plants (1.78 GW), 23 coal plants (5.6 GW), and 46 gas plants (5.9 GW) (Suharsono and Lontoh, 2020). This plan presents a **major opportunity for renewable energy niches in Indonesia**. However, in response to these plans PLN's President Director Zulkifli Zaini stated that although PLN is committed to increasing the share of renewables in Indonesia, the current best option is to replace diesel power plants with gas power plants or coal gasification (Suharsono and Lontoh, 2020). This is **yet another contradiction between plans of the Central Government and the main player in the electricity supply business**. To date PLN have converted 52 diesel plants to gas power plants, and has indicated that it will investigate the renewable alternatives for the diesel plants that are not suitable for conversion to gas, especially in rural locations (Umah, 2020). Considering that many of these diesel generators are in fact located in remote areas, this presents a big opportunity for renewable energy niches as they are the only suitable alternative in many of these locations (Figure 10.1). Since the announcement of these MEMR plans there has been a marked increase in interest in biomass gasification projects (Interviewee 1a and Interviewee 1b - Local Project Developers, 2020).

Formal Rules - Regulations and Laws

In 2017 there were number of regulatory changes regarding tariffs for renewable energy sources. This started with the issuance of MEMR Regulation No. 12/2017, followed by No. 43/2017 in July 2017, and one month later both of these were revoked by the superseding MEMR Regulation No. 50/2017. Electricity tariffs are one of the most sensitive factors that influence the investment environment for renewable energy project developers. Such regulatory uncertainty is a significant risk to project developers and can harm the growth of renewable energy niches as potential developers do not receive a stable long-term signal to invest. Two developments are particularly relevant in the latest MEMR Regulation No. 50/2017: (1) investors will now not automatically be reimbursed for the transmission lines that connect the power plant to the grid, and (2) tariffs in regions where the regional average cost of generation (BPP) is less than the national BPP will be subject to negotiations with PLN, and 85% of the regional BPP when it is higher than the national BPP (for solar, wind, biogas, biomass and ocean energy - other conditions apply for hydropower, geothermal and municipal waste-to-energy plants). Considering that small increases can make significant impacts on returns over the project life time, and that BPPs can vary as much as 15% year-to-year (East Nusa Tenggara 2016 vs 2017 (MEMR, 2017)), these new measures make the renewable energy investment environment much less attractive. Linking the FiT for renewable electricity to the BPP cannot create fair competition as, to varying extents, the local and national BPP is artificially low due to fossil fuel subsidies. In response to increasing pressure from the

President to achieve the 23% renewable target the MEMR started drafting a new regulation in 2020 that aims to improve the electricity pricing for renewable power plants (MEMR, 2020c).

Despite the need to expand small-scale off-grid capacity to supply electricity to remote communities, the current regulatory framework does not address the fact that small-scale projects have higher specific investment costs than large-scale projects. Without such a policy to compensate for these higher costs, the regulatory framework will continue to incentivise large-scale projects, at the expensive of small-scale projects and rural electrification (Setyowati, 2020a).

Having committed to freezing fuel and electricity tariffs until the end of 2019, the Government's decision to introduce a coal price cap and domestic market obligation in 2018 was an attempt to reduce PLN's generation costs and deficits (Sheany, 2018; Bridle, Suharsonno, and Mostafa, 2019). The new MEMR regulation caps the price of coal to \$ 70/tonne of 6000 kcal/kg grade coal. This figure is scaled in proportion to the quality of the coal - and as the energy content of Indonesian coal ranges from 4200 - 4500 kcal/kg, the coal is effectively capped at \$ 37/tonne (Bridle, Suharsonno, and Mostafa, 2019). Analysis from the International Institute for Sustainable Development and the Global Subsidy Institute estimates that the coal price cap has reduced operating expenses of coal power plants by 20% (Bridle, Suharsonno, and Mostafa, 2019). The price cap was accompanied by a domestic market obligation (DMO) which states that 25% of coal produced must be supplied to domestic users. **This measure strengthens the position of centralised, on-grid coal-based power in the regime.** This situation is **worsened by COVID-19**, which has suppressed domestic energy consumption and coal exports, and the **US-China Phase One Trade Deal**, which poses a serious threat to Indonesia's long-term coal exports to China (World Bank and Bank Dunia, 2020). As it is very unlikely that Indonesia's coal exports will be unaffected by this trade deal, the Government may choose to further incentivise domestic consumption of coal as a 'cheap' form of power generation. These events make it very difficult to envisage an escape from a lock-in to coal-based power generation.

In 2017 the MEMR issued a new regulation which would revise the terms of risk sharing, introduce a Build-Own-Operate-Transfer (BOOT) business model, and introduce new penalty mechanisms (MEMR Regulation No. 10/2017 (as amended by MEMR Regulation No. 40/2017 and 10/2018)). The new regulation stipulates that the risks of force majeure, that were previously carried by PLN, will now be shared between PLN and IPPs. IPPs will no longer receive compensatory 'Deemed Dispatch payments' that perhaps allowed them to meet their loan payments; instead the contract could be extended by the length of the shutdown period resulting from the disaster. Penalties were increased for failure of power uptake by PLN, and for failure of deliver power. Lastly, the introduction BOOT scheme meant that at the end of the contract period, which is limited to a maximum of 30 years, IPP facilities must be transferred to PLN. This is mainly a concern for power plants, such as hydro and geothermal, that are expected to operate for much longer than 30 years; and for biomass power plants where the generation facility could be inseparable from the biomass plantation assets. This regulation, that was perceived as inhibitory by renewable energy developers (Institute for Essential Services Reform, 2019), was updated by MEMR Regulation No. 4/2020 which adjusted the cooperation scheme to Build-Own-Operate, removing the obligation to transfer assets at the end of the contract (Ahmed, 2017). This regulation also details a target to develop waste power plants, and obligates PLN to purchase electricity from renewable power plants that were build as part of a grant.

The Job Creation Law, or Omnibus Law, introduced in November 2020 amended 79 laws and over 1,000 regulations - the most significant sudden change in regulatory environment in Indonesia's history. The law is intended to attract investment to facilitate the post-pandemic economic recovery by cutting regulatory red tape regarding investment, employment, immigration, environmental standards, business licensing, and building permits. For the electricity regime, a single business licence is introduced for activities of electricity supply to the public, for captive use, and for transmission and distribution (supporting services) - these previously required separate licenses. The Omnibus law shifts authoritative power from the regional governments to the Central Government - the exact roles are not yet clearly defined - these will be determined by implementing regulations in early 2021. Regional electricity plans are removed - the National Electricity Plan is now formulated by the Central Government, which also no longer is required to consult the Indonesian Parliament.

Under the Omnibus Law, businesses are no longer required to obtain an environmental licence. One of the most controversial changes introduced relates to the Environmental Impact Assessment (AMDAL) - only those directly impacted by the proposed activities can participate in the AMDAL process. Environmental observers such as environmental NGOs and environmental experts, and also members of the public indirectly impacted by the proposed activities, are no longer allowed to participate in the AMDAL process. In the forestry sector, the Central Government is now authorised to determine which forestry areas must be protected and maintained without parliamentary approval. It is no longer required for forestry areas to constitute at least 30% of the rivershed area or island. The justice implications of the Omnibus Law will be discussed further in the following section.

Despite its intention to incentivise investment, the Omnibus Law may do just the opposite - in a letter to the Government, a group of 35 global investors that manage a combined $4.1 trillion in assets, voiced their concerns that the law will have damaging consequences (Jong, 2020a):

> *"Specifically, we fear that proposed changes to the permitting framework, environmental compliance monitoring, public consultation and sanctioning systems will have severe environmental, human rights and labor-related repercussions that introduce significant uncertainty and could impact the attractiveness of Indonesian markets... We recognize Indonesia's progress in protecting tropical forests in recent years, yet the proposed legislation could hamper these efforts... Failure to achieve the goals of the Paris Agreement poses a very real threat to the future stability and health of economies and society... Cutting emissions*

from land use change is key to meeting these goals and while Indonesia can play a pivotal role in this field it is currently at risk of failing to do so, threatening the success of the agreement as a whole."

The domestic and international resistance to this reform, that prioritises Indonesia's economic growth over the environment and worker rights, is an illustrative example of increasing landscape pressures to mitigate climate change and progress with sustainable development goals.

7.2.2 Network of Actors and Social Groups

The share of PLN in electricity generation decreased from 35.4% at the end of 2016, to 60.8% by the end of 2019 (DGE, 2020). Non-PLN power producers consist of IPPs, producers of captive power (IOs), private power utilities (PPUs), and the DGNREEC. With regard to residential electricity consumers, the DGE reported an increase from 60.6 million households at the beginning of 2017, to 71.9 million households by the end of 2019 (DGE, 2020, p. 59).

In recent years the Government has established several new entities in order to gain access to additional funding sources (UNDP, 2020). The establishment of the the National Designated Authorities (NDA) has opened the door to the Green Climate Fund (GCF), which now supports five major projects in Indonesia: Global Subnational Climate Fund, Technical Assistance Facility for the Global Subnational Climate Fund, Indonesia Geothermal Resource Risk Mitigation Project, Climate Investor One, and Indonesia REDD-plus Results-Based Payments (for results period 2014 - 2020). Support from the GCF reached $ 216.9 million in 2020 (GCF, 2020). The access to the GCF REDD-plus programme is a particularly important development for the biomass gasification niche as it makes available funding for projects that can grow biomass on deforested or degraded land.

7.2.3 Material and Technical Elements

Electricity generation from coal-fired power plants increased by 18% in just two years between 2017 (147.9 TWh) and 2019 (174.5 TWh) - accounting for 59% of the supply mix (IEA, 2020b). In 2020 Indonesia is one of just seven countries in the world with new proposals and constructions starting (Shearer, 2020). This pipeline of new coal plants amount to 31.3 GW, making it the fourth largest coal pipeline in the world (Shearer, 2020). In the same two years generation from natural gas increased by 11%, while oil decreased by over 36% following successful measures by the Government to reduce dependence on oil. Since 2017, generation from renewable sources has been on the rise; hydropower increased by 13.6%, geothermal by 10.5%, and biofuels by almost 4500% from 0.24 TWh to 10.7 TWh (Figure 7.5). This increase was to some extent facilitated by deliberate attempts to stimulate electricity generation from biofuels such as the FiT that was introduced in 2012. However, it is also in part likely due to an increasing number of agro-industry actors realising the value of utilising available waste to generate captive power, and sell excess power to PLN; thereby saving on fuel costs and generating additional revenues. Closer inspection of the power contracts reveals that many of the new contracts are held by palm oil plantations for 'excess power' (DGNREEC, 2019).

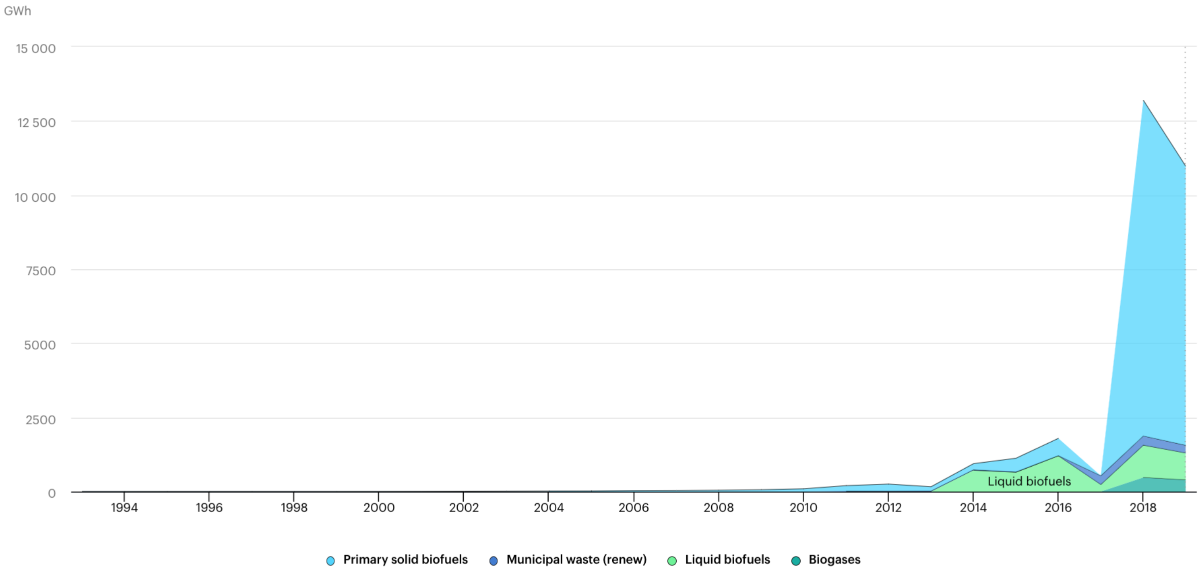


Figure 7.5: Electricity generation from biofuels: solid biomass, liquid biofuels, and biogas (Source: IEA, 2020b).

Transmission and distribution infrastructure expanded significantly in this period to facilitate the growth in electricity capacity, which reach almost 20% between the end of 2016 and the end of 2019 (DGE, 2020). Over 66,000 km of distribution lines and almost 50,000 substations were added, reaching a total of 954,000 km and 482,516.

7.2.4 Energy Justice

Availability

People deserve sufficient energy resources of high quality (suitable to meet their end uses)

By the end of 2017 the IEA estimates that 95.3% of Indonesia's 265 million people had access to electricity (World Bank, 2020b; IEA, 2020b). Despite a steady increase in population to 271 million, the IEA estimates that by 2019 99.5% of the population had access to electricity. Per-capita electricity consumption also steadily increased from 900 kWh in 2017, to 1000 kWh in 2018 (IEA, 2020b). From these figures over 17 million people gained access to electricity between 2017 and 2019. The high-level figures show that Indonesia is making progress on the *availability* (and sufficiency) of electricity, however, some clarification is necessary on the level of electricity supply at which a household is considered electrified. Section 6.2.4 discussed the insufficiency of electricity supply from LTSHE solar lamps that have been distributed as part of the Government's SEHEN program which started in 2012. Presidential Regulation No. 47/2017 introduced a new state-funded program which significantly up-scaled the distribution of these solar lamps across Indonesia - in 2017 alone Rp. 322.8 billion was budgeted to distribute 95,729

LTSHE packages across six eastern provinces: West Nusa Tenggara, East Nusa Tenggara, Maluku, North Maluku, Papua and West Papua. Although these solar lamps are a useful pre-electrification measure, including these households in electrification figures can give a misleading impression of the *availability* of electricity *sufficient* to meet basic needs.

Affordability

All people, including the poor, should pay no more than 10% of their income for energy services

In 2017 the Government removed electricity subsidies for consumer groups with 900 VA connections, with the exception of poor households (P. Burke, 2018). This development was in-line with the Government plans to improve the targeting of electricity subsidies, which still are a heavy burden on the state budget. Electricity tariffs for all consumer groups - the 13 non-subsidised, and 25 subsidised - have remained unchanged since 2017 (ESDM, 2020).

Due Process

Countries should respect due process and human rights in their production and use of energy

Due process violations relating to coal power continued to have grave consequences in this period. The failure of coal mining companies to rehabilitate mining sites is the main violation that was found - this has resulted in further deaths of children and contributed to the severity of floods in Kalimantan (Jong, 2020b; Jong, 2021).

Violations of due process are also prevalent in low carbon electricity projects, particularly large-scale hydropower projects. For example the Batang Toru Hydropower project in North Sumatra failed to disclose information regarding the project impacts, and failed to provide opportunities for public participation as per the requirements of the AMDAL (Setyowati, 2020b). Despite these violations, and strong opposition from local communities and NGOs, the project was able to obtain an AMDAL. The following attempt by civil society to legally contest the project was unsuccessful in court as the project was deemed by the Government to have met all the legal requirements.

Due process violations are also evident in the procurement and bidding process for energy projects. A telling example is the bribery case concerning the $900 million Riau-1 coal power plant in 2019. Allegations involved PLN CEO Sofyan Basir, two senior PLN employees, a member of the House of Representatives, and the Minister for Energy and Mineral Resources (Gokkon, 2019). The following hearings led to the arrest of the two senior PLN employees and the member of the House of Representatives. The Corruption Eradication Commission (KPK) were praised by Dwi Swung of the Indonesian Forum for the Environment (Walhi), saying that the investigation is:

"A step forward in dismantling the connection between dirty coal energy and the practices of corruption by the country's political elite and government" (Gokkon, 2019).

The KPK has handled around 1,000 cases since 2002, often targeting influential members of the DPR, police, ministries, and other judicial institutions (Massola, 2019). Almost a quarter of all corruption cases involved politicians. The continued exposure of Indonesia's political and business elite in corruption scandals shows the vital importance of the KPK. However, its success has also motivated intimidation and political revenge - shocking examples include the attack on the homes of the KPK chair and deputy chair with Molotov cocktails, and the acid attack on a KPK investigator. The recent weakening of the KPK in 2019 has been a cause for national resistance (CNBC, 2019; World Politics Review, 2019) and international criticism (UNCAC, 2019), throwing Indonesia's commitment to anti-corruption into question. This development will limit the KPK's ability to expose violations of due process in Indonesia.

Transparency and Accountability

All people should have access to high quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making

The launching of the 'One Map' in late October 2020 marked a big improvement to public access to high quality information about energy services. The MEMR's One Map is a geoportal database that shows activities and potentials from the mining, oil & gas, and renewable energy industries, in addition to electricity infrastructure, geological features, and zones vulnerable to natural disasters (MEMR, 2020b). However, there is still a lack of publicly available information regarding the environmental impacts of the electricity regime.

The Omnibus Law, which is one of the most significant regulatory reforms in Indonesian history, was drafted in less than six months. The government's reason for expediting the bill was to increase employment during the pandemic, nonetheless, the minimal social dialogue and public participation in the drafting process is a violation of peoples' right to fair, transparent, and accountable forms of decision-making (Mulyanto, 2020). The removal of environmental observers and the indirectly impacted public from the AMDAL process is a major cause for concern as these actors have played a key role in empowering marginalised rural communities in their fight against energy injustice. The new law greatly reduces the audience that has access to information regarding the environmental impacts of proposed projects, and the number of people who can participate in the decision-making process. This development is particularly concerning in the context of the injustices surrounding the AMDAL process in the previous period. Finally, the effective removal of the 'strict liability' clause will make it much more difficult to prove and prosecute business that clear land using forest fires - these businesses will now be much less accountable for the environmental damage they cause.

Sustainability

Energy resources should be depleted with consideration for savings, community development, and precaution

Oil production continued to fall from 838 thousand barrels per day in 2017, to 781 thousand barrels per day by 2019 (BP, 2020). In this period proven oil reserves fell by 21% from 3.2 to 2.5 billion barrels (BP, 2020). At 2019 production levels proven oil reserves will be fully depleted in less than 9 years.

Production of natural gas in this period started decreased by 7% from 72.7 billion m^3 in 2017, to 67.5 billion m^3 by 2019 (BP, 2020). Consumption remained fairly steady - increasing by 1.4% from 43.2 billion m^3 in 2017 to 43.8 billion m^3 by 2019. Proven natural gas reserves however plummeted by almost 50% from 2.9 trillion m^3 in 2017 to 1.4 trillion m^3 in 2019. This sudden drop in proven reserves significantly changes the sustainability of production levels - at the 2016 production levels the proven reserves identified in the same year would last around 40 years, however, at the 2019 production levels and the new value for proven reserves, these reserves would last for around 20 years.

By 2019 coal production had risen to 610 Mt - an increase of 34% in just three years (BP, 2020). The figures for proven coal reserves have fluctuated significantly over the years, nevertheless at the end of 2019 Indonesia had approximately 40 billion tonnes of coal reserves (BP, 2020). At the current production levels of 600 million tonnes per year these reserves will last another 67 years.

Intragenerational Equity

All people have a right to fairly access energy services

Presidential Regulation 47/2017 on the distribution of LTSHE solar lamps to some 2500 villages across Indonesia is an example of increasing government efforts to alleviate the persisting intragenerational inequities in access to electricity. This programme is considered pre-electrification, which will supply unelectrified households with lighting while the Government expand grid electricity access through PLN. The result of including recipients of LTSHE units in electrification figures is that these households, which do not have access to electricity in sufficient quantities to meet their basic needs, suffer *misrecognition* as the statistics no longer show the prevailing disparities in access. Nonetheless, the published electrification ratios still shows that some areas, particularly NTT, have significantly poorer access to electricity than the (Figure 7.6).

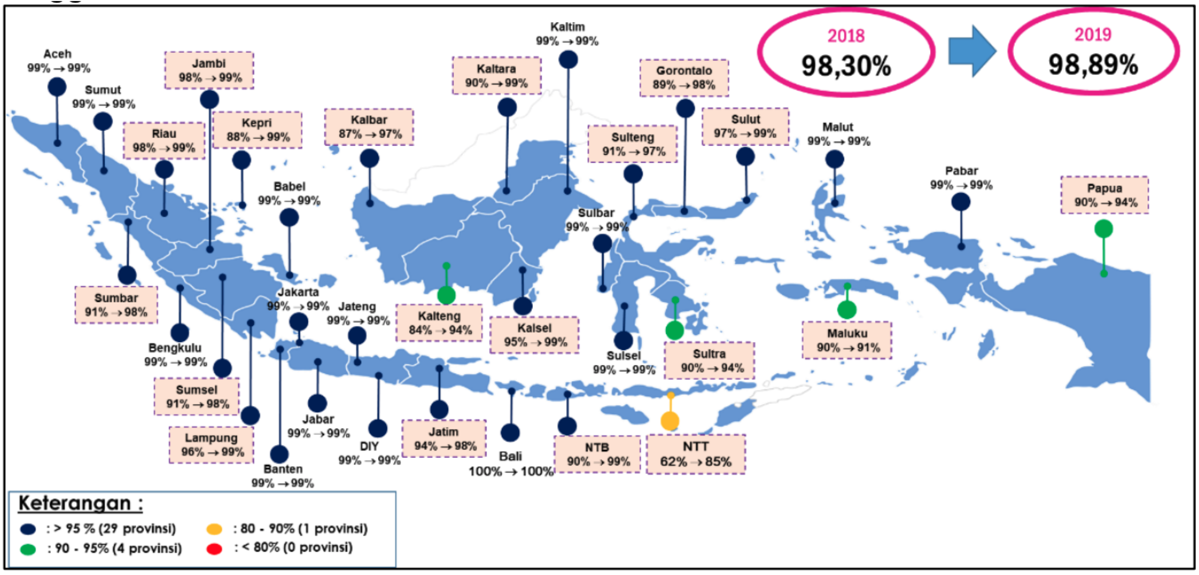


Figure 7.6: Regional electrification rates (Source: Direktorat Jenderal Ketenagalistrikan, 2020).

Intergenerational Equity

Future generations have a right to enjoy a good life undisturbed by the damage of our energy systems inflict on the world today

The current electricity system, in which almost 60% is produced by coal-fired power plants, has a detrimental impact on health, particularly for communities living in close proximity to either the coal mines, or the coal-fired power plants. There are currently 176 coal power plants operating in Indonesia, with a further 39 in the construction phase, 10 permitted, 31 pre-permit, and 52 announced (End Coal, 2020; New Climate Institute, 2020). The New Climate Institute estimate that with no phase-out plan, between 2020 and 2050 Indonesia's coal power plants will emit 7,770 Mt CO_2, 33,400 kt SO_2, 13,500 kt NO_x and 2,400 kt PM_{25} (particulate matter). Combining the PM_{25} estimate with the concentration-response function (relationship between particulate matter concentration and health impacts), it is estimated that the coal-based electricity generation will cause 355,056 premature deaths in Indonesia between 2020 and 2050, or 497,804 deaths considering all affected countries (New Climate Institute, 2020). Stroke is the main cause of death (62%), followed by Ischemic heart disease (31%), lung cancer (4%), and COPD (3%). Without a significant coal-phase out plan Indonesia will be locked-in to a coal-dominated electricity regime for decades into the future. The negative impacts of the coal regime span beyond air pollution to water and soil contamination, and landscape destruction which have resulted in an increase in the frequency and intensity of floods (Fünfgeld, 2016). Rural communities in which peoples' livelihoods are based on agriculture are severely impacted by this environmental damage - rice, fruit, and fish harvests have been reported to be reduced by half due to the accumulation of mud in fields and fish farms (Fünfgeld, 2016). Indeed, future generations will bear the brunt of the negative impacts caused by the coal-dominated electricity regime - which include the loss of life and livelihood caused by particulate matter emissions, coal mining activities (see below), and from the increasing severity of climate change.

Responsibility

All actors have a responsibility to protect the natural environment and minimize energy-related environmental threats

Coal mining activities have continued to be the greatest cause of energy-related environmental degradation. The current '**responsibility**' measure in place for coal mining activities is the obligation for companies to restore the land to "rona awal", or "original condition". However, as with the previous period, the weak enforcement of these regulations means restoration efforts rarely take place (Darmawan, 2019; Jong, 2021). Furthermore, recent research has highlighted the need to revise the current legislation as "restoring forests on abandoned coal mines is unrealistic in any tangible time frame, even in the best-case scenarios" - the legislation therefore currently gives the false idea that the extreme degradation caused by mining activities can be reversed (Woodbury and Arbainsyah, 2020).

The recent dramatic increases in electricity generation from biomass combustion raises questions for the assessment of *energy* justice, as commodity driven deforestation was the main cause of tree cover loss between 2001 and 2019 (Global Forest Watch, 2020). However, the biomass feedstocks combusted to generate electricity are the waste fractions of valuable agricultural products; for example, palm *kernel shell* as opposed to palm *oil*. These waste fractions had previously been left to degrade naturally and therefore the electricity generation from their combustion has not been a driver for deforestation.

The Omnibus Law has significantly reduced the environmental protection measures in place for energy projects - this has been a major source of criticism both domestically and internationally. Although the impacts of this law are yet to be seen, this law is a clear example of the central government failing to fulfil their responsibility to protect the natural environment and minimise energy-related environmental threats.

Resistance

Energy injustices must be actively, deliberately opposed

Resistance regarding the climate crisis has been increasing in recent years, globally, and within Indonesia. In late 2019 hundreds of activists, students, and members of around 50 environmental groups marched throughout Jakarta, protesting the Government's inaction and demanding stronger measures to mitigate the climate crisis (Aqil, 2019).

Resistance to specific energy projects has continued in recent years. Unsurprisingly the vast majority of resistance is to coal power plants, and coal mining activities. Regarding coal power plants, local communities report being showered in coal dust which covers their home, and their crops - resulting in respiratory problems and reduced crop yields (Darmawan, 2019; Suprapto, 2020; Syahni, 2021). Regarding the mining activities, communities are still campaigning for stronger enforcement of mine restoration activities that are required by law - failure to do so has resulted in many horrific cases of children drowning (Jong, 2020b).

The Omnibus Law has sparked widespread opposition both domestically and internationally. Protests have taken place all over Indonesia since the first announcements of the proposed bill. In October for example over 8,000 people took to the streets to protest the injustices threatened by the Omnibus Law - these relate to *transparency and accountability*, *responsibility*, and *intersectionality* - the bill was formulated with minimal social dialogue and participation and weakens labour rights and environmental protection (Tani, 2020).

Intersectionality

Expanding the idea of recognitional justice to encapsulate new and evolving identities in modern societies, as well as acknowledging how the realization of energy justice is linked to other forms of justice e.g. socio-economic, political and environmental

Energy justice is closely related to social justice. The current state of the electricity regime reinforces a number of social injustices. The lack of engagement with local communities has led to misrecognition, or disregard, of their needs and failure to compensate them for the negative impacts of projects that fall disproportionately on them. It is common for people in such communities to view themselves as ‘small citizens’, whose basic citizens’ rights do not apply, and whose needs are disregarded in decision making processes (Fünfgeld, 2016). This is especially true for indigenous communities. The ‘One Map’ policy is an illustrative example of how indigenous populations are marginalised in Indonesia. The project, which began in 2011 and was launched in October 2020, attempts to resolve conflicts over land tenure due to absent, incomplete, or inconsistent records and maps held by communities, corporations, and various government ministries and agencies. The unification of land rights data is an important step for easing land tenure issues that have plagued Indonesia for many years - by 2020 it was estimated that 40% of Indonesia’s land area was disputed, for example disputes over permits between spatial plans and forest area, which accounted for 16% of disputes (Aqil, 2020). Once fully implemented, the **One Map will drastically reduce opportunities for contesting land tenure**. It is therefore of the upmost importance that such a map has been created in an open, participatory manner, with fully access to high quality information. However, the One Map has currently not included the land rights of indigenous communities; an omission that has triggered a public debate about indigenous rights. The official verdict is that these maps of indigenous land cannot be included until they are all recognised by local government bylaws (Jong, 2018). Regardless, the omission of indigenous land rights in the One Map is a clear example of how indigenous populations suffer nonrecognition.

7.3 Niche 2017 - 2020

The fixed FiT for biomass power plants that was in place 2012 - 2016 has been considered in this study as the first example of a (soft) shielding measure provided by the regime. The introduction of MEMR Regulation No. 50/2017 meant that new biomass power plants would only be able to sell electricity for 85% of the BPP; which is artificially lowered by prevailing fossil fuel subsidies. Although the pre-2017 FiT was widely considered as insufficient, the shift from a fixed tariff, to one linked to 85% of the BPP significantly worsened the investment environment. As before, the main niche shielding is provided by multi-lateral and bi-lateral aid agencies.

Several landscape pressures have been destabilising the regime and creating opportunities for the niche in recent years: (1) millions of people still do not have access to electricity, (2) deficits from oil imports and subsidies, and (3) climate change. These landscape pressures have shifted the Government's strategy, and resulted in changes to the formal rules and targets - approach 100% electrification by 2020, replace all diesel generators by 2023, generate 23% of electricity from renewable sources, and repair degraded land. Niche actors attract support from regime and landscape actors based on their orientation with respect to landscape pressures; for example, niche projects that target unelectrified rural communities are well-positioned with respect to (1) and (3), whereas projects that target the replacement of diesel power plants are well-positioned with respect to (2) and (3). Furthermore, CIFOR's recent research on integrating bioenergy and land restoration has created an opportunity for niche actors to offer two solutions to the climate change landscape pressure - low carbon renewable energy production, and land restoration. Indeed, projects that capitalise on this opportunity to grow bioenergy crops on degraded land offer a unique solution to landscape pressures that other niche projects do not - which refers not only to the biomass gasification projects using agro-industry waste or wood from tree plantations, but also to other niche technologies that address the climate change landscape pressure such as micro-hydro and solar PV.

7.3.1 Network Formation

Composition

Trillion, ITB, DGNREEC, and CPI continued to operate during this period. Through they're involvement with STT-PLN and PLN Bali, Trillion were able to attract the attention of PLN Nusa Tenggara Timur (NTT), which recently commissioned a trial project in NTT to gasify municipal solid waste (MSW) for rural electrification. ITB continued to their research activities on biomass gasification, but in this period they were no longer actively involved in any implementation projects. The DGNREEC actor group working on the Sumba project remained relatively unchanged throughout this period, both in terms of actors, and roles.

In comparison with the previous period two new projects have initiated by CPI - one in Mentawai Island

Regency in 2017, and one in Nusa Tenggara Timur in 2020. The Mentawai project brought together a diverse group of actors: project developers CPI, gasifier system manufacturer ASCENT, CPI's subcontractor IKPT (owned by Japanese Toyo Engineering Corporation), financiers Millennium Challenge Corporation (MCC), Bappenas, local government, local cooperation, bamboo seedling suppliers Nusa Verde (owned by Belgian Oprins), ecological consultants, electricity network installers PT. IJT Padang, and the local people of three villages - Madobag, Matotonan, and Saliguma. The Mentawai project is ASCENT's second project in Indonesia (the first being the Sumba Iconic Island project) - this allows them to draw on learning experiences in both settings in the absence of formal cross-project communication and shared learning processes.

CPI's NTT project uses the Mentawai project as a template and so has very similar actor group composition and roles - private elements and the local community will be aggregated into a special purpose vehicle (SPV), which will act as the owner of the biomass power plant and sell electricity to the electricity off-taker and supplier of government subsidy PLN (in this case PLN NTT). A village cooperative, in this case a regionally owned enterprise (PT Flobamor), will manage the collection of biomass from the local community and enter into a long-term feedstock supply agreement with the SPV.

Alignment

CIFOR has taken up a key role in aligning the expectations of niche actors. Their research output points the niche towards bioenergy crop cultivation on degraded land. Although some new projects aim to align themselves with this gap identified by CIFOR, other biomass gasification projects still plan to utilise agro-industry waste for feedstock. They further note that the key actor in the electricity sector, PLN, is still not directly involved in the development of the technology - expansion of this technology would be greatly accelerated if PLN becomes more involved. In this regard, PLN's (NTT) increasing interest in, and exposure to, biomass gasification projects is a key development for the niche. This involvement started with the Sumba project (which began in the previous time period), and has developed through the commissioning of a MSW gasification trial with Trillion and CPI's 1 MW project in Ponu.

In terms of experience with operating projects, information on operational experience on CPI's Mentawai's project offers some insights into the coordination of actors within this group. Lack of communication and coordination between stakeholders at the handover stage of the project caused significant problems in the early phases of the project - while IKPT and ASCENT technicians returned home for several months the plant was left unoccupied and suffered from theft and equipment damage. The director of the Saliguma plant told reporters that it was not clear what was happening at this stage and that there had been no handover from project developer to Bappenas, and Bappenas to the local government. By January, technicians from IKPT and ASCENT had returned to find that much of the machinery was not working. Lack of communication and coordination between stakeholders was also evident by the amount of confusion regarding the several month shutdown in May 2020; which in itself is a result of organisational problems on a higher level that concerns the distribution of state budgets.

7.3.2 Learning Processes

Three main actors were actively learning in this period - the DGNREEC continued to work on the implementation of the Sumba project, Trillion developed a gas engine to compliment their gasifier systems, and CPI have implemented two projects - one in Mentawai and one in Ponu.

User Experience

On the Mentawai project, which involves the local community as feedstock suppliers, actors learned that the users were reluctant to supply the feedstock to the power plants as the price received for the feedstock was considered too low for the amount of time and effort required for its cultivation, harvesting, size reduction, drying, and delivery (Mariadi, 2020b; Interviewee 6 - Operator, 2020). The plant coordinator at the Saliguma plant told Mentawai Rita that their power plant has been using a combination of residue wood and diesel so far - users are reluctant to collect the bamboo as it is located further away than the available residue wood. Users are also reluctant to supply wood in the required small pieces (3 - 5cm) as it takes too much time and effort. Similar experiences were found at the other two power plants in Madobag and Matotonan - users said it takes a lot of time and effort to collect 2 - 5 trunks of bamboo and chop it into small pieces. In order to increase the motivation of users to supply feedstock to the power plants the price was increased from Rp. 250kg to Rp. 700/kg (Interviewee 6 - Operator, 2020).

This actor group also learned that the local community were also not motivated to go to the power plants to collect the ash waste, which could be used as fertiliser for the bamboo cultivation (Interviewee 6 - Operator, 2020).

The local community were happy with the electricity supply, but unsatisfied with the short operational hours. The power plants have been operating for 6 hours each day, from 6pm to 12am. Operators hope to increase this to 12 hours in 2021, and 24 hours the following year (Interviewee 6 - Operator, 2020). However, another challenge faced by the operators is that the absorption capacity of the village is much lower than anticipated - after one year it was estimated that the power plants could operate at 50% capacity, however, in the second year the communities were only able to absorb 12 - 15% of the power plants' capacity (Interviewee 6 - Operator, 2020). The low absorption capacity of the local communities was a key learning to come from the Mentawai project; which itself represents the most extreme environment in which niche projects could operate due to the remoteness of the location, high prevalence of poverty, and extreme lack of prior access to electricity.

Technical and Infrastructure Developments

The Mentawai project faced a number of technical difficulties throughout the construction and operation of the power plants. The three plants have only managed to operate for around 6 hours each day. The need to repeatedly startup the plant has detrimental effects to the plant performance and maintenance requirements - the condensible tars remaining in the pipes between shutdown and startup fouls the equipment - leading to frequent required maintenance. The frequent startups and resulting maintenance activities has led to significant diesel consumption and thus has negatively effected both the environmental impact of the power plants and the economic performance. In 2019 operating costs were much higher than expected, at around Rp. 32,000/kW - compared to PLN's non-subsidized electricity cost of around Rp. 3000 (Interviewee 6 - Operator, 2020).

Each of Mentawai's power plants require eight operators per shift - a total of 24 operators are required to operate the three plants which produce a total of 700 kW. Although this is a valuable source of employment for the local community, the large number of operators required is a major source of financial inefficiency - by comparison a 1 MW power plant requires just two operators (Interviewee 6 - Operator, 2020). Increased process automation has been identified by actors as a key opportunity for further development (Interviewee 6 - Operator, 2020).

The economic viability of Trillion's commercial projects hinges on the savings from reduced diesel consumption. Low oil prices therefore had a detrimental effect on the economic viability of commercial gasifiers. Responding to these shifting landscape pressures Trillion began to develop a gas engine system - starting in 2017 with the search for a suitable engine block, implementing technical modifications, and progressing to intensive testing phase in late 2018. Trillion's soft launch of this gas engine in 2020 was hampered by the outbreak of COVID, nonetheless this unit will be used in PLN's MSW gasification project on Bangka island.

Industrial Development

The CPI actor group were able to overcome the challenges involved in transporting large amounts of specialised heavy equipment to extremely remote locations in Mentawai that have very poor access roads. The actor group made use of specialised heavy off-road trucks and a helicopter to transport equipment to the site. A challenge that persists past the construction phase is the supply of spare parts, or technical assistance to these remote areas with such limited access.

The projects experienced problems with the replacement gas filters. The filter cloth used at the start of operation were from ASCENT, who are based in India. These need to be replaced once they become saturated with particulate matter from the flue gas. Initially, the operators ordered replacement filter cloth from Indonesian firms in Medan and Bandung in order to save time and money. However, these filter cloths were found to be unsuitable for use as they became saturated much quicker and sometimes caught fire during operation. Through this experimentation the actors learned about that the domestically available replacements are not suitable or compatible with the ASCENT gasifier system. Replacements needed to be ordered from ASCENT in India - without careful planning this long supply chain could result in significant delays and shutdown time. Long supply chains for replacement parts is a challenge inherent to operating with specialised equipment in remote locations.

Policy and Regulatory Environment

CIFOR warn that land tenure has been a major barrier to industrial plantation (HTI) development and should be addressed by creating clearer licences, accelerating the slow licensing processes, and integrating smallholders (Pirard, Bär, Dermawan, et al., 2016). Encouragingly, a project developer recently indicated that following the land concession regulation changes in 2015 there are no clear regulatory barriers for biomass gasification projects (Interviewee 1a and Interviewee 1b - Local Project Developers, 2020). This is not to say that more cannot be done to incentivise such projects, it simply means that prior to the recent land reforms, biomass gasification projects that planned to cultivate feedstock were unfeasible as large corporate holders of land concessions could get much higher prices from the export market (Interviewee 1a and Interviewee 1b - Local Project Developers, 2020).

The linking of the electricity price to PLN's BPP has resulted in a greater incentive to implement projects in eastern provinces where the BPP is higher (Interviewee 5 - International Project Facilitator, 2020) - see Figure A.14. This is a challenge for the biomass gasification niche as NTT has a more arid climate - the majority of biomass potential from agribusinesses, and degraded lands for feedstock cultivation, are located in other provinces of Indonesia (Interviewee 5 - International Project Facilitator, 2020; Jaung et al., 2018).

The increasing domestic utilisation of agro-industry waste products like palm kernel shells has also been put under pressure but the export market. The introduction of an excise duty on palm kernel shells was intended to provide some protection for the growing number of domestic consumers. However, actors have found that this regulation has not yet been very effective as the balance between domestic and export markets is largely determined by the foreign exchange rate between USD and IDR (Interviewee 4 - Researcher and Industrial User, 2020).

Biomass Potential

Publicly available information regarding the location of bioenergy potential has also improved since 2017. Firstly, the MEMR's Map of New and Renewable Energy shows the spatial distribution of waste from the production of palm oil, rice, sugarcane, pulp and paper, tapioca, coffee, and wood (Figure 7.7 - MEMR, 2020b). The map currently only shows the location of these waste biomass sources - it does not show land suitable for bioenergy crop cultivation such as the existing tree plantations (Figure 6.2), or degraded land. Regarding the latter, Juang et al. have identified around 4.49 Mha of degraded land that has "limited functions for food production, carbon storage, and conservation of biodiversity and native vegetation" (Jaung et al., 2018, p. 1), yet is suitable for *C. calothyrsus* or *G. sepium* - the two woody biomass species studied (Figure 7.8). Opportunities for niche projects to resolve landscape pressure could be made more explicit by combining the spatial data regarding bioenergy potential and suitable degraded lands, with spatial data for unelectrified households and diesel generators (discussed in Chapter 10).

Figure 7.7: Spatial distribution of bioenergy potential (Source: DGNREEC, 2020).

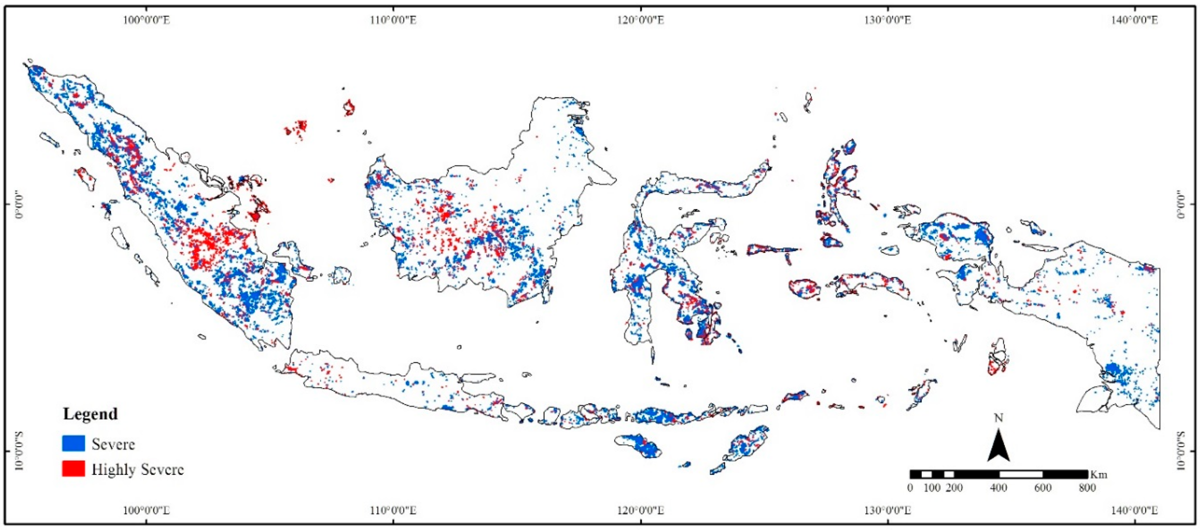


Figure 7.8: Spatial distribution of degraded lands suitable for bioenergy crop cultivation (Source: Jaung et al., 2018). The blue and red patches represent areas of severe, and highly severe degradation.

CPI has conducted an in-depth analysis of biomass potential in the area surrounding Ponu on NTT, assessing the potential and feasibility of several biomass sources: Bambusa blumeana (bamboo), Acacia nilotica (Pohon Duri), and Gliricidia sepium (Gamal) (PT CPI - PT PP Energi, 2019). Their analysis included an environmental description of the Ponu area (soil type, rainfall, ecosystems, etc.), assessment of existing biomass sources, and potential development of new biomass feedstocks and estimated yields (propagation, planting, soil treatment, harvesting, productivity, and cost). Through this study CPI and their partners were able to learn a considerable amount about the biomass potential in the region. In the development of this recent project CPI also make use of CIFOR's research on degraded land - specifically mentioning the possibility of planting feedstocks on degraded land to reap additional benefits.

The rise in palm kernel shell utilisation resulted in the increases in biomass power generation in this period. Prior to this wide-spread utilisation in palm oil mills the palm kernel shells were considered waste products and lay in enormous piles unused (Interviewee 4 - Researcher and Industrial User, 2020). The recent increases in utilisation therefore raises the question what quantity of palm kernel shell remains once the mill self-utilisation is accounted for. Some independent research has indicated that 60 - 70% of the palm kernel shell still remains unused, and is therefore available for the domestic, and international markets (Interviewee 4 - Researcher and Industrial User, 2020).

Business Models

In Mentawai, the reluctance of the local community to participate as feedstock supplier highlighted a key challenge for business models that add value by incorporating users as feedstock suppliers - the challenge is how to guarantee a consistent supply of sufficient and good quality feedstock over the entire lifespan of the power plant. Failure to supply the power plant with sufficient desired feedstock will result in backup fuels like diesel being used, which greatly changes the economic, environment, and social impact of the project. This risk must also be assessed and addressed by the project financiers, especially in commercial projects unsupported by donors. Concerns over feedstock supply and quality is one of the main arguments for integrated plantation business models (General Electric, 2014; Widayati et al., 2017).

CPI built on their experiences in Mentawai to develop their business model in Ponu:

"Learning from the business model that was built for Mentawai, lesson learned of the project to be commercially feasible, three separate investments need to be in place: i) developers should only focus on the power plant development, ii) PLN will should provide the network distribution and off-taker guarantee, and iii) regional government, Ministry of Villages, and/or Ministry of Environment and Forestry should be responsible for biomass farming activities including funding and training for communities" (PT CPI - PT PP Energi, 2019, p. 13)

Although this project is still in the development stages there are a few notable additions to CPI's more recent project in terms of value creation: firstly in their pre-feasibility study they have mentioned the possibility of sourcing money for land restoration that can be achieved through feedstock cultivation, and secondly they have now explicitly included the sale of the process by-product biochar. The biochar, which is sold as fertiliser, will be sold for $ 25/per tonne, which could contribute around 3% of the total annual revenues throughout the duration of the project (PT CPI - PT PP Energi, 2019).

Second-Order Learning

Recalling from Section 3.2.1, second-order learning occurs when actors learn about the values associated with the technology through real-world implementation. This type of learning creates shifts in problem framing or problem solving/priorities. In the previous period CPI worked on a MSW gasification project in Bali which was aligned with PLN's need to increase power production from renewables, and the potential to contribute to the alleviation of two landscape factors: waste management in Bali and climate change mitigation. In this period one can observe a shift in problem framing, orienting strongly towards rural development, poverty alleviation, and a second dimension of the climate change landscape pressure - land restoration. The latter is an illustrative example of problem framing shift, where CPI have learned about the potential of biomass gasification to contribute to land restoration through CIFOR's research.

7.3.3 Voicing and Shaping Expectations

In dialogues at Indonesia's House of Regional Representatives, CIFOR emphasise that bioenergy crops should not be cultivated in food production areas, nor should they result in the conversion of natural forests, instead bioenergy production should utilise degraded land (CIFOR, 2017). CIFOR's recent publications, and involvement in dialogues between many key stakeholders in Indonesia have helped to shape and align stakeholder expectations. An example of such an event is the International Workshop on Developing Science- and Evidence-based Policy and Practice of Bioenergy in Indonesia within the Context of Sustainable Development, which involved a number of regime members, including MEMR and the Ministry and Environment and Forestry (Widayati et al., 2017). Based on their publications, their expectations are that the cultivation of bioenergy crops on degraded lands could yield environmental benefits if the identified land cannot support native vegetation and biodiversity (Widayati et al., 2017; Borchard et al., 2017; Rahman et al., 2019). Bioenergy crops cultivated on these lands would contribute to increased carbon storage, reduced soil erosion, and, by restoring lost habitat would also lead to improved biodiversity ((Singh et al., 2015; Blanco-Canqui, 2016) cited in (Artati et al., 2019)). Such a strategy would also bring social benefits through the creation of jobs in rural areas, increased energy availability and security, and depending on the business model could also provide additional revenue through bioenergy crop sales. CIFOR have identified several biofuel crops, which are well-suited for cultivation on degraded land: nyamplung, caliandra, bamboo, and malapari (Jaung et al., 2018; Sharma, Wahono, and Baral, 2018). Referencing recently discontinued projects that were part of the Government's Energy Sufficient Villages program, CIFOR further voiced their expectations that future projects should take a bottom-up approach instead of top-down to ensure that the project meets the needs and preferences of the landowner (Artati et al., 2019). Projects that are aligned with user preferences and needs create motivated users, that facilitate the stable supply of good quality feedstock, and therefore stable operation, power supply, and allows for the realisation of maximum social and environmental benefits.

7.3.4 Energy Justice

Availability

People deserve sufficient energy resources of high quality (suitable to meet their end uses)

The only project that reached operation in this period is CPI's Mentawai project, which aims to address the insufficient availability of energy resources in three underdeveloped villages in Mentawai Island Regency: Madobag, Matotonan, and Saliguma. CPI's project aims to supply 1,204 households, around 6,000 people, with electricity; thereby contributing to the availability and sufficiency of energy resources, increasing the electrification rates in these villages to 100%, 100%, and 77%, respectively. The outcomes of the project so far have been limited by a range of problems that have caused the power plants to operate in frequently. Although no specific data is available regarding the actual levels of electricity consumption per household, the experiences described above suggest that although the plants have contribute to increased electricity availability, the level of supply in terms of quantity and reliability may be below the level at which could be considered sufficient.

Affordability

All people, including the poor, should pay no more than 10% of their income for energy services

The power plants in Mentawai sell electricity to PLN for \$ 0.15/kWh, who then sell it to the community for \$ 0.031/kWh (Alliance for Rural Electrification, 2019). The low electricity price offered by PLN, which is almost five times lower than the price the power plant sells electricity to PLN, is essential for facilitating electricity access to in these communities where household incomes are very low. Table 7.1 below shows the number of people in each income group, for each village - in Madobag for example 73% of the village live in poverty (defined in their report as less than Rp. 7,780 /day (\$ 0.55). Without additional information regarding electricity consumption levels it is not possible to comment on the share of energy spending in these communities.

Transparency and Accountability

All people should have access to high quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making

This justice principle is highly relevant to the early development phases of the project. Data is available for the two CPI projects that were initiated in this period. In both projects CPI have developed a community engagement strategy and implemented a participatory approach, which have ensured that the local communities have access to high quality information about the project, and are involved in decision-making processes. Project developers first visited the sites to learn about the local context such as the social structures, energy needs, socio-economic environment, and the culture, which also includes learning about the cultural importance of different plant species. Teams were made to manage the various community engagement activities that included: personal interviews, workshops and training, focus groups and forums, public town hall meetings, surveys, and stakeholder panels. On the Ponu project engagement activities allowed actors to understand the community's preference for Gamal biomass feedstock over bamboo, which was initially proposed. The project is now predominantly planning to utilise

Gamal feedstock for the biomass power plant. This is a good example of how the community has been involved in core decision-making processes - this is in stark contrast to the accounts from both coal and large-scale hydropower projects described in Section 6.2.4.

Intragenerational Equity

All people have a right to fairly access energy services

One of the main goals of CPI's Mentawai project is to address intragenerational inequities in electricity provision. Just considering the *access* to electricity, there is an enormous difference between these three villages, and other villages or cities across Indonesia such as Jakarta, where 100% of the population have access to electricity. This project therefore contributes to greater intragenerational equity in Indonesia by supplying around 6,000 homes with electricity, many of them for the first time.

Responsibility

All actors have a responsibility to protect the natural environment and minimize energy-related environmental threats

The project's environmental impact is very positive as it offsets diesel combustion with a locally grown renewable sources (bamboo), which only requires soil nutrients, water, and sunlight to grow. This is in stark contrast to diesel fuel, which has a very long and emission-intense supply chain - crude oil is extracted from the ground, a fraction is processed into diesel fuel, which then transported from the production site to Indonesia (Indonesia is a net importer of oil), and then transported great distances using many forms of fossil fuel-based transport to arrive in the remote location. In terms of the feedstock, users planted the bamboo seedlings in their fields between existing plants, or in empty fields. To avoid negative social and environmental impacts related to monoculture bioenergy crop develop MCC explicitly prohibited this - through this project land cannot be cleared to grow the bamboo. Furthermore, the use of ASCENT's dry filtering system ensures that no liquid waste stream is produced - unlike most other small-scale biomass gasification projects to date, which have utilised water scrubbers, thereby producing a liquid waste stream contaminated with impurities that have been removed from the flue gas such as particulate matter and tars. The design choice was also due to the absence of a suitable local water supply, nonetheless, the dry filter system is a responsible design choice that ensures that environmental risks are minimised.

Intersectionality

Expanding the idea of recognitional justice to encapsulate new and evolving identities in modern societies, as well as acknowledging how the realization of energy justice is linked to other forms of justice e.g. socio-economic, political and environmental

CPI, and their partners, operated in a very unique and challenging environment but were very diligent in their consideration of justice when conceptualising the project. It is first necessary to elaborate on the context of Mentawai. Mentawai is a remote island off the coast of West Sumatra and is one of Indonesia's most unique islands culturally and ecologically. The indigenous population are descents of the Austronesian people who arrived on the Mentawai Islands thousands of years ago (Clean Power Indonesia, 2017). There are no strong forms of political hierarchy on the islands; people are organised into patrilineal family groups. Livelihoods on the Mentawai Islands mainly consist of subsistence farming, hunting, and gathering forest products. Actors had to be very diligent operating in such an environment - first the gender dimension of the project will be discussed.

In Mentawaian society there are distinct gender norms - woman manage household finances and are responsible for the majority of the housework, while men are responsible for selling farm and forestry products in markets. Access to opportunities such as training and public activities is still very much limited to men on Siberut:

"Females are often marginalized; in keeping with MCC's and MCA-I's corporate emphases, this project will make the inclusion of females in village meetings, job opportunities, and project benefits as standard practice " (Clean Power Indonesia, 2017, p. 16).

A minimum quota of 30% women was stipulated for people trained as power plant personnel. Outwith the power plant operators the male household heads were responsible for planting, maintaining, and harvesting the bamboo plantations, while women would nurture the bamboo seedlings and manage household electricity accounts inline with previous responsibilities for managing household accounts.

This project also has a strong environmental justice dimension, which *intersects* with the *responsibility* principle of energy justice, where actors have a responsibility to protect the environment and minimise environmental damage. Since it's separation from the mainland some 500,000 years ago Siberut Island has been undergoing its own evolutionary process, developing a wide array of endemic plant and animal species (Clean Power Indonesia, 2017). Accordingly, the island has been recognised as a Biosphere Reserve by the Indonesian Government and UNESCO since 1981. The Western part of the island has been a designated National Park since 1993 and can only be accessed through Madobag and Matotonan - two of the villages targeted by CPI's project. The actors involved have ensured, in accordance with the MCC's stipulations, that the bamboo feedstock is cultivated in combination with existing crops, or in unused spaces on existing fields - and that no forest area is cleared for its cultivation. This responsible feedstock production ensures that the project's impact on Mentawai's unique ecosystem is minimised.

By targeting three of the least developed communities in the Mentawai island Regency, which is also West Sumatra's least developed regency, the CPI project has a strong socio-economic justice dimension. In total the project would supply 700 kW electricity to 1204 households across these three villages. Table

7.1 describes the socio-economic context of these three villages with respect to income levels and number of businesses.

Table 7.1: Socio-economy of Madobag, Matotonan, and Saliguma villages in Mentawai Island Regency (Source: Clean Power Indonesia, 2017, p. 11).

Household beneficiaries	Madobag	Matotonan	Saliguma
Total household number	537	270	397
Poor households (less than Rp. 7,780 per day)	393 (73%)	149 (55%)	191 (48%)
Near poor households (less than Rp. 7,781 - 9,350 per day)	27 (5%)	19 (7%)	19 (5%)
Near not poor households (less than Rp. 9,351 - 11,687 per day)	53 (10%)	18 (7%)	27 (7%)
Not poor households (more than Rp. 11,687 per day)	64 (12%)	84 (31%)	160 (40%)
Estimated total household income (Rp. per day)	6,706	10,013	17,032
Retailing businesses	5	5	10

In Madobag, Matotonan, and Saliguma, large portions of the population live below the national poverty line of Rp. 7,780/day ($ 0.55) - 73%, 55%, and 48%, respectively. In these communities, with high poverty levels and extremely limited access to electricity, projects like CPI's can have massive impacts on lives and livelihoods. The societal benefits from CIP's project stem from the offset of expensive and polluting diesel fuel, the training and employment of 10 - 15 local operators in each village, and from electricity supply that amongst other benefits, facilitates new economic activity. The relative magnitudes of the total economic benefits for each user group is a function of the number of users and the assumed consumption levels over time. The results of CPI's initial economic analysis for these user groups is shown below in Table 7.2. The socio-economic justice derived from electricity access and facilitated economic development *intersects* with the *availability*, *affordability*, and *intragenerational equity* principles - these marginalised people gain access to sufficient energy resources through this project, and are able to afford it due to the Government's subsidy system in which PLN purchases electricity from the power plant for $ 0.15/kWh, and sells it to the consumers for $ 0.031/kWh.

Table 7.2: Distribution of economic benefits among stakeholders (Source: Clean Power Indonesia, 2017, p. 12).

Beneficiary group	NPV (million Rp.)	NPV (million US$)
Assigned Worker	53,908	3.95
Poor household	208,726	15.29
Near poor household	17,489	1.28
Near not poor household	34,218	2.51
Not poor household	109,814	8.04

However, the benefits derived from the project rely on the successful and consistent operation of the project. Mentawai Ritas's report on August 25 2020 highlights a few problems experienced since the handover of the power plants to the Mentawai regional development agency (BAPPEDA), the Mentawai regional government, and Perusda Mentawai. Their interviews reveal that technical problems led to intermittent supply, and when electricity was available, it was sufficient for lighting, but not more energy intense devices like televisions (Mariadi, 2020a). Their report also revealed that the power plants have not been operating for several months due to delayed subsidy from the central government. The lack of funds meant that spare parts important for operation of the power plants, such as the gas filters, could not be ordered. It also meant that during this downtime the social benefits of employment and electricity access were not realised.

7.4 Summary

As with the previous period, niche activities were **actively shielded** by both the Indonesian government, and various international donors. All projects also benefited from the **passive shielding** of rural locations. The climate change landscape pressure intensified in this period - evident from the increased frequency of regulations aimed at supporting renewables in order to achieve the 23% target by 2025. Actors responsible for the development of renewables in Indonesia confirmed this intensifying pressure to implement renewable energy projects - reported as pressure on government ministries (Interviewee 8 - Government, 2020), and ease of securing support for projects (Interviewee 1a and Interviewee 1b - Local Project Developers, 2020).

Projects continued to experience challenges with feedstock security and operating the power plants - two key factors that hindered the success of projects in this period. Nonetheless, several significant learning processes were seen in this period regarding: feedstock security, biomass potential, and business model. CPI's experience in Mentawai show the challenges of feedstock security when involving the local community as feedstock suppliers. However, this experimentation also showed that by opting for such a business model the project could add value by providing additional revenue streams for people in low-income rural communities - thus alleviating poverty (*intersectionality*). Furthermore, CIFOR's research on biomass cultivation on degraded lands has provided a means for niche actors to position themselves as solutions to both dimensions of the climate change landscape pressure.

Regulatory developments in this period did not necessarily align with the intensifying climate change landscape pressure that was articulated in Indonesia's renewable target for the electricity sector. Throughout this period the electricity price for niche projects was linked to 85% of PLN's generation cost - which in turn is heavily influenced by fossil-fuel subsidies. Such a policy is detrimental to the commercial feasibility of projects and so has not facilitated any experimentation with this business model.

8 Discussion

8.1 Reflection on Research Design and Methodology

Research Design

This thesis has sought to incorporate energy justice theory into Sustainability Transitions Research, and apply an integrated framework to study the development of biomass gasification in Indonesia. The addition of energy justice analysis, and the historical approach together made the scope of the research project very large - this has limited the level of detail possible for the analysis in a finite research period. A research project performed over a longer time, or one which was more focused on the present time would be able to perform a more in-depth analysis.

Data Collection

Data collection for this research was challenging due in part to the enormous scope, which involved investigating developments at the landscape, regime, and niche levels, in addition to energy justice at the regime and niche levels. Another challenge of data collection was the inconsistencies in data between different sources - for example different actors reporting on the same project without mentioning one another in their lists of actors. A key success of this research lies in the richness of the data and analysis presented - this is mainly the result of a extensive desk research, in which several hundred documents were reviewed over the course of the project.

Data collection for the analysis of energy justice and niche developments was particularly challenging due to the limited availability and accessibility of information. Primary data was collected through video interviews, written interviews, and via additional documents shared by interviewees. In total eight video interviews and two written interviews were conducted. Three interviewees were able to provide additional documents which proved very useful for the analysis. The primary data collected greatly improved the analysis mainly of the niche level, where actors shared their knowledge about the niche network, learning processes, and their expectations. The interviews did not add many insights to the regime or landscape levels as these were already well investigated through desk research. The interviews themselves also did not greatly contribute to the energy justice analysis - this was in part due to the lack of operational gasification projects and lack of project monitoring beyond the first few months.

A key limitation of the energy justice analysis is the lack of ethnographic research - this research would greatly benefit from several months of field research in the villages supplied by biomass gasification projects. This would allow for a more complete analysis of energy justice and biomass gasification. Data collection for energy justice analysis at the regime level utilised desk research to uncover statistics, reports, and articles - the analysis is therefore limited by the lack of available data on energy-related injustices in Indonesia.

Selection of Frameworks

Consideration of energy justice has added a wealth of insights to this research. At the niche level the energy justice analysis has shown that biomass gasification projects throughout the studied period have positively impacted energy justice in Indonesia. At the regime level the energy justice analysis has provided an overview of how developments at in the electricity sector have impacted energy justice. Combining the findings from the energy justice analysis on the niche and regime levels leads to the conclusion that the biomass gasification niche is particularly well-suited to alleviate many of the injustices created and reinforced by Indonesia's electricity regime. In contrast to standalone sustainability transitions research studies, this combined energy justice research is able to provide a strong case for the continued development of the biomass gasification niche - as it can out-perform both traditional technologies and competing niche technologies with respect to energy justice.

Sovacool's ten principle energy justice framework was chosen over the traditional three (more recently five) tenets of energy justice framework. Although Sovacool's framework may seem very different, it is important to recall that the ten principles were formulated by considering the impact of energy systems on these tenets of energy justice - each principle therefore relates to one or more of these core tenets of justice. The framework also addressed the fact that energy justice theory to date has been built exclusively on Western notions of justice, and lacked consideration of non-human life. **The selection of this framework is therefore highly *appropriate* for this case study** - based in the East, and in a location with such rich biodiversity.

Of the principles included in the analysis, five in particular add insights beyond which are seen in case studies that use the three tenet framework. These principles are: *availability*, *affordability*, *sustainability*, *responsibility*, and *intersectionality*. Firstly, in terms of *availability*, the explicit mention of sufficiency challenges the researcher to assess both the quantity of electricity supplied, and the reliability of the supply - this has led to the criticism of several government rural electrification programs and the identification of opportunities for niche projects that can improve the availability of electricity in these communities. The *affordability* term is an important addition to the framework - although due to Indonesia's subsidy system it does not lead to a distinction between energy sources it does emphasise the importance of Indonesia's electricity subsidies for facilitating energy access despite the high prevalence of poverty, particularly in rural areas. Due to slow changes in policy, electricity tariffs have become more targeted - ensuring that the bottom consumer groups benefit from government support, while overconsumption in higher consumer groups is not encouraged. Consideration of the *sustainability* principle has highlighted the need for Indonesia to seriously commit to the energy transition as gas and oil reserves will be depleted in around 20 years and 9 years, respectively. The *responsibility* principle, which also goes beyond the scope of a typical energy justice analysis, provided insights into not only the importance of minimising the environmental impact of projects, but also how energy projects, especially coal mining activities, have had devastating impacts on the environment. Finally the last principle of energy justice, *intersectionality*, has enhanced the typical energy justice analysis by uncovering illustrative examples of how energy infrastructure at the niche and regime levels have impacted other forms of justice. At the niche this research has shown that biomass gasification projects, particularly CPI's recent Mentawai project, has been able to alleviate other forms of injustice relating to socio-economy and gender. At the regime level this research has shown how energy infrastructure, in particular coal mining activities, have caused health, environmental, and social injustices. These points illustrate how **Sovacool's framework has enriched the analysis of energy justice** in this case study.

Sovacool's framework is extremely broad and can facilitate a much more comprehensive analysis of energy systems than the standalone three (or five) tenet energy justice framework. Due to the broad nature of framework, any detailed study will need to collect and analyse a very large amount of data - this may be fine for longer research projects involving a team of researchers, however, the implication of this research project, which has been conducted by just one researcher over a ten month period, is that the level of detail in the energy justice analysis is relatively low for some principles. The level of detail is also influenced by the integrated approach of the research, and the historical nature of the case study. Despite being limited by the availability of data, time, and the large scope of the research, the energy justice analysis presented provides a some useful insights into how energy projects at the niche and regime levels have impacted energy justice.

The MLP was the core framework to which both the SNM and Energy Justice frameworks were applied. The MLP framework greatly enhanced the research in comparison to a stand-alone SNM, Energy Justice, or integrated SNM-Energy Justice framework. Indeed, by adding the regime and landscape analysis to the niche analysis this research benefited from a wealth of insights on how these levels have influenced the development of the niche. At the landscape level; the 1970s oil crises, declining domestic oil reserves, prevailing inequities between rural and urban areas, and climate change have exerted pressure on the regime level nested below, creating 'windows of opportunity' for niches like biomass gasification. Niche activities were supported and implemented by actors responding to these landscape pressures - from Trillion's commercial plantations responding to high oil prices, or CPI responding to the prevailing inequities between rural and urban areas, and climate change. At the regime level these landscape pressures have led to range of changes, starting with a change in the network with the creation of the DGNREEC in 2010, followed by series of regulatory and policy changes that have provided some incentives for the development of niche technologies like biomass gasification. The consideration of the regime level has proved very useful for the energy justice analysis too - by comparing the energy justice analysis for the niche and regime levels one can see that renewable energy technologies, biomass gasification in particular, are well-positioned to alleviate some of the injustices created by the regime. This analysis importantly leads to the understanding that **traditional technologies are unable to alleviate these injustices, particularly: *sustainability*, *intragenerational equity*, *intergenerational equity*, *responsibility*, and some dimensions of the *intersectionality* principle such as health**. This finding - in which niche technologies like biomass gasification are required to alleviate energy injustice - is actually another ‘window of opportunity’ for niche technologies. The MLP therefore compliments both the SNM and Energy Justice frameworks very well.

In comparison to a standalone MLP study, the SNM framework has facilitated a more in-depth analysis of the niche level. The consideration of niche shielding has linked well with the landscape level of the MLP, which has created the opportunities for both passive and active shielding - the only commercial actor, Trillion, has sold gasifiers in passively shielded rural areas, while all other projects have also been actively shielded by both the Indonesian government, and international donors. Furthermore, the division of learning processes into seven categories has enriched the analysis in comparison to the MLP niche analysis - especially regarding the learning about biomass potential, business models, and the second order learning observed in the final period.

Due to the level of detail that is necessary for an in-depth SNM analysis it is typically used in case studies that focus on the present time. The implication of utilising the SNM framework in this *historical* case study is that the level of detail attained by the end of the research is lower in comparison - this is in part due to time constraints, and in part due to the nature of information necessary for a full SNM analysis - this data, such as the intensity of relations between actors in the niche network, is only available for recent recent years, and most likely must be obtained through primary data collection methods such as interviews.

Integration of Frameworks

The MLP formed the base of the combined analytical framework. The SNM framework was integrated into the MLP at the niche level, replacing the MLP niche analysis. The integration of energy justice theory is not as straightforward. Sovacool’s energy justice framework is suitable for application to the regime and niche levels of the MLP. The energy justice analysis was added to the end of the regime and niche sections in each time period. At the niche level the energy justice analysis captured the Societal and Environmental Impact learning process and therefore this level of niche analysis was omitted. Keeping the energy justice analysis at the end of the regime and niche sections meant that the structure of these sections remained ordered and logical - first, developments were described and analysed, and then the impact that these developments had on energy justice was discussed.

However, of the three frameworks utilised in this research, only the MLP and SNM can be considered well-integrated. The energy justice framework has been presented as an *addition* to the integrated MLP-SNM frameworks, rather than being *integrated* into these frameworks. A key reflection for this research is on the opportunities and challenges involved in *integrating* energy justice theory into the SNM and MLP frameworks.

Considering the interaction of the Energy Justice and SNM frameworks, the energy justice analysis fits very well into the Societal and Environmental Impact learning process. However, placing the energy justice analysis in this section would disturb the flow and balance of the SNM analysis, which traditionally progresses from shielding, to nurturing process (network formation, learning processes, and voicing and shaping expectations), to empowerment activities. It was therefore chosen to keep the energy justice analysis as a separate subsection following the SNM niche analysis (while omitting the SNM Societal and Environmental Impact learning process). The implication of this is that the energy justice analysis on the niche level is not *integrated* into the SNM framework - it is *added* as an assessment following the SNM analysis.

Considering the interaction between the energy justice framework and the MLP, Sovacool's broad ten principle framework creates significant overlaps with the MLP regime analysis. The selection of regime dimensions from G. Verbong and F. Geels, 2007 has limited the scope of the regime analysis to the material and technical elements, network of actors and social groups, and the rules. The material and technical elements dimension considers the technology and infrastructure required to generate, transmit, and distribute electricity. The scale of these elements determine the *availability* of electricity, whereas the specific choices of generating technologies determine the *sustainability* of electricity supply, *intragenerational*, and *intergenerational equity*, and the impact of the regime on a broad range of justice principles like health justice - *intersectionality*. For the case of Indonesia, the regime rules determine the *affordability* of electricity. The nature and enforcement of regime rules also impact the environment (*responsibility*), and peoples' human rights and access to fair decision-making processes (*due process* and *transparency & accountability*). Finally, the *resistance* energy justice principle relates to both the rules of the regime, and its material and technical elements. Despite these opportunities to integrate justice analysis into the regime analysis, one must question whether this indeed adds value, or whether the division of the justice principles between the different regime dimensions detracts from the energy justice analysis. In this research it was chosen to keep the energy justice analysis as a separate subsection following the regime analysis - the implication of this decision is that the frameworks are not integrated, but considered one after the other, much like the niche analysis.

8.2 Practical and Academic Contribution

Practical Contribution

In the last 20 years there has been no reviews of biomass gasification in Indonesia. With the exception of the IIEE, developers have only published information regarding the plans for projects - no information is published regarding the outcomes. Combined with the lack of inter-project communication this has resulted in the current state of the niche, in which **none of the actors are fully aware of the projects that have been implemented, or what their outcome was** - this was evident from the interviews of government officials, international donors, international researchers, domestic researchers, project developers, operators, and manufacturers. A key practical contribution of this thesis is the extensive documentation of niche projects and their learning experiences - this will facilitate improved learning between project actor groups.

A key relevance for niche actors is how they can optimally select sites for projects by navigating landscape pressures, energy injustices, biomass potential, and the locally available tariffs (regime rules linking sale price to BPP) - discussed in greater detail in the Recommendations Chapter. As biomass gasification still lacks a strong commercial case (low oil and electricity prices), it is essential that niche developers attract support from both the Indonesian government, and the international community of donors. The key to attracting this support is aligning projects with (1) the landscape pressures - rural development (poverty, electricity access, and job opportunities), climate change (both emissions and land-use and land-use change dimensions), and oil consumption (burden of subsidies and energy insecurity due to dwindling reserves), and (2) the energy injustices caused by the electricity regime detailed in this study. This finding is also of high relevance to developers of other renewable energy niches.

The practical relevance for policy makers is three-fold - first, to understand the factors that have influenced the development of biomass gasification; second, to understand the importance of biomass gasification as a solution to landscape pressures and energy injustices; and third, to gain an insight into how energy infrastructure can be assessed with respect to justice. With regard to the first, it is importance to understand that the linking of the electricity sale price for niche actors, to PLN's local generation cost (BPP) that is based on subsidised fossil fuels, not only discourages niche developers, it also provides a greater incentive for niche actors to focus on eastern provinces where the BPP is higher. This is challenging for the biomass gasification niche as there is greater potential for biomass (both in terms of agribusiness waste and degraded lands for crop cultivation) in other parts of Indonesia, more unelectrified homes outside of eastern Indonesia, and stronger competition from the solar PV niche in the more arid eastern Indonesia. With regard to the second point, policy makers must understand that even in comparison to other renewable energy niches, the biomass gasification niche has a greater potential to alleviate the many landscape pressures and energy injustices Indonesia currently faces - this is evident from CPI's recent Mentawai project which not only supplies renewable electricity to three impoverished villages, but also provides 20 - 25 jobs per power plant, addresses gender inequality, and provides a means for additional income through biomass cultivation. Finally regarding the third point, this research has provided some insight into how activities relating to electricity generation, at the regime and niche levels, have impacted energy justice. The energy justice framework presented in this case study goes far beyond the Indonesian Government's current conceptualisation of justice and therefore provides some insight into how adopting a more comprehensive view of justice could facilitate a fair comparison of electricity technologies and overview of trade-offs between justice principles.

Academic Contribution

The academic contribution of this study largely lies in its integration of energy justice theory into STR - despite being integral to the concept of sustainability, there has been very little explicit engagement with justice theory in this field (Eames and Hunt, 2013; Hopwood, Mellor, and O'Brien, 2005; Jenkins, McCauley, et al., 2016). The need to integrate justice theory was communicated in a recent review of the field's current state of the art and future directions (Köhler et al., 2019). The integration of energy justice into the MLP draws on the guidance provided by Jenkins, Sovacool, and McCauley, 2018, whilst choosing to adopt the ten principle energy justice framework from Sovacool, M. Burke, et al., 2017. **This research is the first to incorporate energy justice theory into a historical STR case study, and also the first to apply Sovacool's framework in this way.** The energy justice analysis in this research was limited due to the large scope of the project, time, and lack of data, nonetheless a key academic contribution lies in the attempt to integrate energy justice and STR frameworks.

In the MLP regime analysis, a division was made in this research between formal rules relating to strategy, and those related to implementing law, policies, and regulations. Developments at the regime level do not happen spontaneously - they are a result of a continually evolving array of landscape factors that exert change forces on the regime. The strategies identified in the analysis are an articulation of the landscape pressures that are experienced by regime actors. The practical relevance of this deviation from standard practice is that it is important, especially for those unfamiliar with the Indonesian context, to understand the *priorities* of regime and also niche actors - for example, while those from high-income Western countries may be primarily concerned with climate change mitigation, the priority for Indonesian actors is poverty alleviation - in this case through the provision of electricity, job opportunities, and additional revenue streams. The academic relevance of this analysis is that, in comparison to typical MLP studies, it makes a stronger connection between landscape pressures, and the formal rules of the regime.

Integration of the SNM and MLP frameworks dates back to 2012, and since then just 34 articles have been published which utilise both frameworks. Furthermore, none of these research papers have applied the integrated framework over a long transition period of around 40 years, as is more common with case studies solely using the MLP framework. A further academic contribution of this research is therefore the novel application of the SNM framework over a long transition period. This choice is not without its limitations (discussed above), nonetheless the findings presented in this research have shown that integrating the SNM framework into a historical MLP study can greatly enhance the analysis of the niche level.

9 Conclusion

9.1 Answering the Sub-Questions

Sub-Question 1

How can transition frameworks and justice theory be combined to study the biomass gasification niche?

The analytical framework utilised in this research consists of the MLP and SNM frameworks from the field of sustainability transitions research, and Sovacool's ten principle energy justice framework. The MLP is the foundation of the integrated framework - providing the conceptualisation of three nested levels - the landscape, the regime, and the niche. SNM theory is integrated into the MLP by substituting the MLP niche level analysis. The Energy Justice framework acts as a 'lens' through which the electricity regime of the MLP and niche projects are viewed. The energy justice analysis is included at the end of the regime and niche analyses for each transition period. For the regime level, all energy justice principles are considered, whereas for the niche level, several principles were omitted - *sustainability* and *intergenerational equity* were omitted as their analysis did not add value (biomass gasification is a renewable energy niche), while *resistance* was omitted as no examples of resistance to niche projects were found. The energy justice analysis at the niche level captured the Societal and Environmental Impact learning process - this dimension was therefore omitted from the SNM analysis.

The conceptualisation of transitions drew on MLP theory, where these are a result of interactions between all three levels - landscape pressures create tensions between the different dimensions of the regime, destabilising it and creating 'windows of opportunity' for niche innovations that have developed through three nurturing processes: network formation, learning processes, and voice and shaping expectations (SNM theory). The Energy Justice framework contributes to this conceptualisation of transitions by showing that, if framed on the political level, the different dimensions of energy justice can act as landscape pressures, exerting pressure on the incumbent regime. Some dimensions of energy justice can therefore act as factors; creating 'windows of opportunity' for niche technologies that are able to alleviate the injustices created and reinforced by the incumbent regime.

Sub-Question 2

How has the electricity regime performed with respect to energy justice?

Since 1980 Indonesia has made massive strides with respect to the *availability* of electricity - the share of the population with access to electricity rose from just 4% in 1980 to 99.5% by 2019 (Asian Development Bank, 2016; IEA, 2020b). This is massive achievement considering between 1980 and 2019 Indonesia's population grew from 147 million to over 270 million. In the context of high poverty levels - in which over 90% of the population in 1980 and over 20% of the population in 2018 lived below the $ 3.20 /day poverty line - the increase in electricity access is also a testament to the *affordability* of electricity. Social justice for all Indonesians - the fifth term of the Pancasila philosophy is a core reason behind the high electricity tariffs which have allowed even those in poverty to access energy resources.

However, the published figures for electricity access do not adequately consider the *sufficiency* of supply. For example several rural electrification, and pre-electrification programs such as the government's SEHEN programme, supply people with electricity in quantities that are below that which is required for their basic needs. Despite this, these households are considered electrified and thus contribute to the electrification statistics - these households therefore not only suffer *distributional* injustice through poor access to electricity, but also *misrecognition* as the electrification statistics fail to recognise that these communities still lack access to electricity in sufficient quantities to meet their basic needs. Millions of people still remain without sufficient electricity supply and therefore suffer *intragenerational inequity.*

Data regarding *due process* in Indonesia's electricity sector mainly concern the coal industry and large-scale hydropower infrastructure. The violations in *due process*, failure to protect the environment (*responsibility*), and lack of *transparency and accountability* has led to injustices on an enormous scale. The Mining Law No. 4/2009 obligates companies to perform an environmental impact assessment (*responsibility*), define development opportunities for the surrounding communities (*intragenerational equity*), and finance the rehabilitation of the land once mining activities have ceased (*responsibility - based on restorative justice*). However, the lack of regulatory enforcement (at all levels of government) and high prevalence of corruption has created an environment where regulatory processes can be either are completely ignored, or implemented merely symbolically (Fünfgeld, 2020). The consequence of *due process* violations have been severe - nationwide between 2014 and 2018 it is estimated that over 140 people have died in abandoned open-pit mines (Fünfgeld, 2020). *Due process* violations are also prevalent in low carbon electricity projects, particularly large-scale hydropower projects like the Batang Toru Hydropower project in North Sumatra. *Resistance* to (energy-related) injustice dates back to the Government's first attempts to reduce subsidies in the 1990s. Public *resistance* to energy infrastructure has mainly been in response to unjust coal mining activities and large-scale hydropower plants.

The heavy reliance on fossil fuels has implications for the *sustainability* and *intergenerational equity* principles of energy justice. At 2019 consumption levels Indonesia's reserves of oil, natural gas, and coal will be fully depleted in less than 9 years, around 20 years, and 67 years, respectively (BP, 2020). Although consumption of finite fossil fuels is inherently unsustainable, the rate at which Indonesia's fossil fuel reserves are being depleted, particularly oil and natural gas, is alarming. Considering the scale of proved reserves, Indonesia's heavy reliance on coal-powered generation is not surprising, and although it has facilitated a massive increase in the *availability* of electricity and facilitated gains welfare, it has also been the source of many injustices. In the absence of a coal phase-out plan, between 2020 and 2050 the emissions from Indonesia's coal fleet will cause around 355,000 premature deaths in Indonesia alone (New Climate Institute, 2020). The landscape destruction and contamination of water sources caused by coal mining activities have had detrimental impacts on human life (particularly marginalised rural communities), and non-human life. Finally, future generations will bear the brunt of the live and livelihood loss resulting from the increasing severity of climate change.

Sub-Question 3

How has the biomass gasification niche performed with respect to energy justice?

Since the earliest niche experiments in 1980, biomass gasification projects have attempted to alleviate some of the injustices caused by Indonesia's electricity regime. Biomass gasification projects have all been implemented in rural settings, and the majority have aimed to supply electricity to the local communities. By targeting rural communities that have been marginalised by poor *availability* of electricity, projects have sought to alleviate *intragenerational inequity.* Due to the lack of regulations regarding small-scale distributed power generation no examples of *due process* violations have been found. The data on recent niche projects in Munduk with IIEE, Sumba with the DGNREEC, and Mentawai and Ponu with CPI, niche actors have engaged with local communities from the start of projects - providing access to high quality information about the project and involving them in the decision making (*transparency and accountability*).

In comparison to diesel power plants, which have been widely implemented to increase access to electricity in rural areas, niche projects utilise renewable biomass feedstocks - thereby improving the *sustainability* of electricity provision. Niche projects have also contributed to improved *intergenerational equity* through lower net emissions, and in the case of CPI's Mentawai project that cultivates bamboo on marginal land, has yielded additional environmental benefits such as soil stability and increased carbon sequestration.

In terms of *intersectionality* the main contribution of niche projects has been in the targeting of low-income rural communities with limited access to electricity - the majority of projects have not only aimed to supply electricity that is *sufficient* for basic needs, but also in quantities that can facilitate rural development. CPI's business model used in Mentawai, in which villages become feedstock suppliers, has a particularly strong impact on *socio-economic justice* - in Madobag for example, almost 400 households, or around 73% of the village, live on less than Rp. 7,780 per day ($ 0.56). The training and employment of around 20 local people for operator positions, and the opportunity to sell feedstock to the power plant significantly improves the socio-economic position of many villagers. Mentawai was the first niche project shown to contribute to *gender justice* - the project's main financiers MCC stipulated a minimum quota for 30% women in the trained operators - although this falls short of equality, it is hugely significant in the context of the traditional Mentawaian society. However, the potential contributions of niche projects to energy justice throughout the studied period have been limited by the lack of success in operating the biomass gasification power plants.

Sub-Question 4

What are the main factors that have influenced the development of the biomass gasification niche?

Evolving landscape pressure throughout the examined period have created several 'windows of opportunity' for niche developers. In 1980 niche activities were driven by (net) oil-importing Western countries under pressure to investigate alternative forms of electricity generation that was caused by the world oil crises in the 1970s. These niche projects, funded through bi-lateral aid agreements, also aligned to the landscape pressures of widespread poverty and poor access to electricity in Indonesia. Oil expenditure for rural industries increased due to decreasing subsidies that were a result of Indonesia's shift from a massive net oil exporter, to a net importer by the early 2000s. The gasifier manufacturer Trillion capitalised on this opportunity - offering dual-fuel gasifier systems (diesel and various agro-industry waste products) that can reduce fuel costs by 70%. Despite considerable progress in electricity provision, electricity access and poverty are landscape pressures that persist in the present day, and are particularly intense in rural locations - corresponding to the *(un)availability* and *intragenerational (in)equity* energy justice principles. Niche projects prior to 2012 were primarily aligned with these landscape pressures. Niche support from the international community started again in 2012 with several high profile projects - USAID in Munduk and Hivos on Sumba - both also aligning to the growing landscape pressure to mitigate climate change - corresponding to the *sustainability*, *intergenerational equity*, *responsibility*, and *intersectionality* energy justice principles. Since then, support from the international community for climate change mitigation projects has been increasing - the MCC have supported CPI's influential project in Mentawai, and several donor have supported CIFOR's research on bioenergy crop cultivation on degraded land.

The landscape pressures acting on the regime have resulted in a number of changes to the regime rules and network that have positively influenced the development of the niche. Since Indonesia's first strategic energy plan in 2006 the government has articulated the need to reduce oil consumption. In the context of the increasing landscape pressure to mitigate climate change the DGNREEC was formed in 2010 and has since been one of the main drivers of renewables, including the biomass gasification niche (J. Marquardt, 2016; Interviewee 3 - Researcher, 2020). The DGNREEC financed ITB gasification projects in five locations in Riau 2011 - 2014 and has been a key project facilitator on the Sumba project. Since 2012 a number of formal rules have been introduced in order to incentivise biomass gasification projects - these started with standardised FiTs, and later linked the FiT price to PLN's local generation cost (BPP). Although these policies are in place, the price at which biomass gasification projects can sell electricity is insufficient to incentivise commercial projects (Interviewee 5 - International Project Facilitator, 2020; Interviewee 8 - Government, 2020).

This research has described the development of the niche with respect to several nurturing processes

- network formation, learning processes, and the voicing and shaping of expectations. The niche has attracted a wide variety of actors over the past 40 years - project developers, manufacturers, research institutions, international donors, financial institutions, NGOs, local and regional government, and users (agribusinesses and rural communities). These actors have formed groups around the learning processes such as R&D, pilot projects, demonstration projects, etc. Although the various actor groups have exhibited some degree of alignment through project similarities, there has been *minimal* interaction between the different actor throughout the entire time period. This lack of shared learning has meant that actors have not been able to effectively learn from the accumulating experiences of other niche projects - this void in communication also means that there has been limited examples of reinforcing nurturing processes and also limited examples of second-order learning. This research has shown that recent projects still face similar challenges to those faced in 1980, and have not learned from the recommendations articulated at the time. This is therefore a factor that has to some extent inhibited the development of the niche. A factor that has positively influenced the development of the niche has been CPI's recent experimentation with business models that allow niche projects to align themselves to several landscape pressures - the need to improve rural electricity access, increase rural development, reduce oil consumption (diesel power plants in rural areas), and mitigate climate change.

9.2 Answering the Main Research Question

What are the main factors that have influenced the development of biomass gasification in Indonesia since 1980 and how has the niche contributed to energy justice?

The development of biomass gasification in Indonesia has been largely driven by support from international donors responding to landscape pressures - this started with the 1970s oil crises, and shifted to the intensifying pressure to mitigate climate change in recent years. Trends in government oil expenditure and prevailing *intragenerational inequity* between urban and rural areas have also been key sources of motivation for the support of biomass gasification within Indonesia. For developers of biomass gasification projects, such as CPI and ITB, the ability to align project proposals with major landscape pressures has been a key factor that has secured support from international and national actors. However, the development of the niche has been somewhat hindered by the lack of a coordinated national plan for technology development and implementation, in addition to the lack of cross-project learning processes.

Niche projects have sought to alleviate some of the injustices caused by the electricity regime - particularly with respect to five principles of energy justice - *availability* of electricity, the *intragenerational inequity* in supply, *sustainability*, *intergenerational equity*, *responsibility*, and *intersectionality* of justice (mainly *socio-economic justice*). The lack of success to date has however limited the potentially high impacts of niche projects - several recommendations are made below which could help to improve niche development and realise these positive impacts.

10 Recommendations

10.1 Niche

Navigating Landscape Pressures and Potential

Opportunities for the biomass gasification are determined by landscape pressures and the availability of biomass feedstocks - both of which have a **spatial dimension**. For landscape pressures: (1) access to electricity is lowest in rural areas where centralised power generation is prohibitively expensive, (2) poverty levels are highest in rural areas, (3) oil expenditure is higher in rural areas due to the long supply chain and old inefficient diesel power plants, and (4) rural communities that predominantly work in the traditional services and agriculture sectors will bear the brunt of climate change (decreased yields from increased extreme weather events etc.), and finally (5) the location of deforested and degraded land in need of restoration. Niche projects can either utilise agro-industry waste such as palm kernel shell, rice husk, etc. or cultivate feedstock. Considering the latter, the key opportunity lies in feedstock cultivation on degraded land, which allows projects to align themselves with the land-use and land-use change dimension of climate change mitigation. This is particularly true for clumping bamboo species that still provide ecosystem services after some of the canes are harvested. Preliminary national data for the spatial distribution and severity of degraded land was published in 2018 by CIFOR, while they currently working on local level maps (Jaung et al., 2018; Interviewee 7 - Researcher, 2020). This research also investigated the suitability of five specific bioenergy crops and determined the locations of degraded land that are suitable for each crop - further research will also consider other crops, including various bamboo species. In terms of agro-industry waste, the MEMR One Map provides the locations of agro-industry waste potential. This map also shows the locations of all power infrastructure, including the locations of diesel power plants. Combining the available data on biomass feedstock locations (or land suitable for cultivation), and the location of diesel power plants **allows niche actors to identify the locations where projects can align themselves to several landscape pressures**. A simple example of this is shown below in Figure 10.1, which overlays the location of diesel power plants (purple) and grid infrastructure with the location of degraded land (red and blue). Areas in which diesel power plants are located near degraded land represent key opportunities for niche developers to offer a solution to at least two landscape pressures: deficits from oil imports and subsidies, and climate change. A thorough assessment of potential sites should combine spatial data of higher granularity (local level) for all identified landscape pressures (and biomass potentials if applicable).

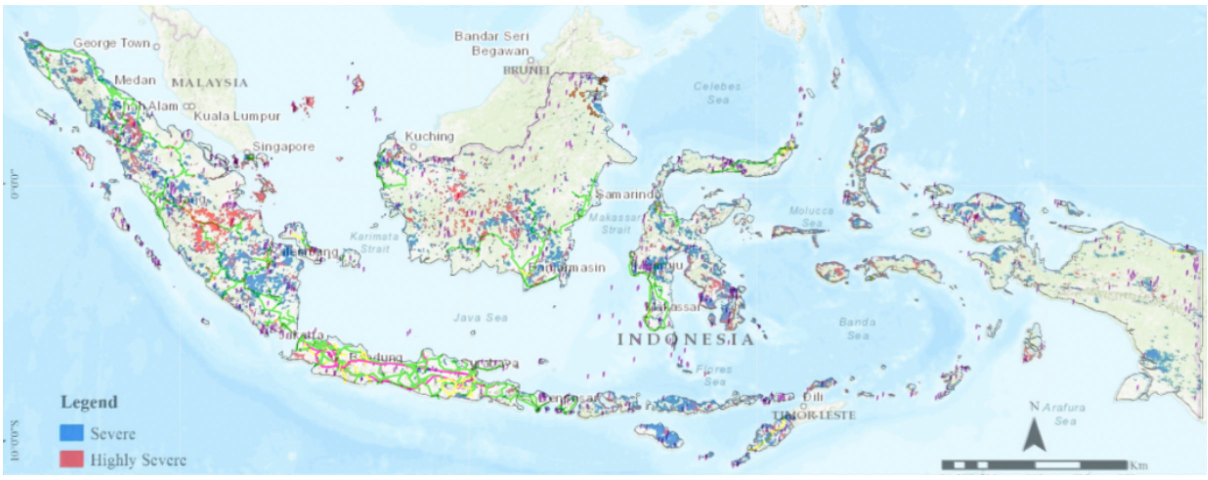


Figure 10.1: Spatial distribution of degraded lands suitable for bioenergy crop cultivation (Source: Jaung et al., 2018). The blue and red patches represent areas of severe, and highly severe degradation. This data is superimposed on the DGNREEC's OneMap which shows the electricity grid infrastructure, and diesel plants, which are shown by purple lightning bolts (DGNREEC, 2020).

Mitigating Threats - Internal and External

The high potential of niche projects to alleviate some of the injustices of the electricity regime has been limited by lack of project success. Projects throughout the examined 40 year time period have failed for a variety of socio-technical reasons - several of which have been observed since the first niche experiments in 1980. The various actor groups identified throughout this study have operated in isolation - with minimal or no cross-project communication. Shared learning is limited to the scarcely available reports on project experiences which briefly discuss the challenges experienced and provide some recommendations for future projects - in recent times these have only been published by the IIEE and ITB (Fatimah et al., 2014; Susanto, 2018). The niche benefited from interest from the World Bank and the Belgian government in the early stages of the niche prior to 2000, when a number of more comprehensive reviews were performed (Stassen, 1995; Maniatis, 1989). The lack of cross-project communication - either direct (workshops, seminars, conferences, etc.) or indirect (publishing learning experiences) - has meant that actors have not been able to learn from the wealth of experiences built up over the history of the niche. **Improved cross-project communication is key to further niche development**. However, making learning experiences such as negative results from projects accessible to the public is perhaps a threat to niche development as the negative results can shape the expectations of existing and potential niche actors, which can lead to their withdrawal from the niche network and an overall decrease in resources (SNM theory). The recommendation is therefore to create a platform where niche developers can share learning experiences privately and freely amongst the actor network, without the fear of negatively influencing the development of the niche.

Several key threats still remain: (1) security of feedstock supply, (2) diligent operation, and (3) competition from other technologies. Firstly, in projects that utilise agro-industry waste, a key threat is that the price of the feedstock increases significantly due to the evolution of its market either domestically or internationally (Fatimah et al., 2014; Interviewee 4 - Researcher and Industrial User, 2020; Interviewee 1a and Interviewee 1b - Local Project Developers, 2020). In projects that rely on the local community for feedstock cultivation a key threat is that the community are, or become, unwilling to supply the feedstock - which can either lead to the disruption of supply or much higher feedstock prices (Interviewee 6 - Operator, 2020). For the first case, government support is likely required to protect niche actors from feedstock prices that will make projects unfeasible. In the latter, CPI is already experimenting and learning how to mitigate this through thorough community engagement to foster support, and through defining necessary roles and responsibilities of various project actors to ensure the security of feedstock supply.

One of the main causes for project failures has been poor operational practice - a key challenge for projects that train and employ local people to operate the power plant is ensuring that sufficient training is budgeted for in the project, and that further training activities can continue during the project's lifespan to mitigate for turnover in staff. Another strategy to mitigate for this is the increasing use of automation in the power plant - which can significantly reduce the responsibilities of the operator (Interviewee 6 - Operator, 2020).

Finally, biomass gasification projects face competition from both traditional technologies, and niche innovations. The 'window of opportunity' that was created by the landscape pressure to increase access to electricity in rural areas has been a key opportunity for biomass gasification niche actors, however, in several major projects the solar PV and micro-hydro niches have been the preferred option, due to the ease of operation and lower capital costs. Following their experiences in Munduk, the IIEE suggested that future projects are located in areas that are not well-suited to solar PV or micro-hydro power plants as these options will be preferred by the community due to the easier operation and maintenance (Fatimah et al., 2014). The recent plans to replace all diesel power plants is another key 'window of opportunity' for the biomass gasification niche - however, as the government is mainly considering the use of gas and coal gasification power plants, the biomass gasification niche faces strong competition from traditional sources. Niche developers must present strong cases for the application of biomass gasification instead of traditional sources - justice should form the core of this case.

10.2 Regime

Justice is at the heart of the Indonesian state's identity - which dates back to the introduction of the Pancasila philosophy in 1945. The recent articulation of an energy justice vision in Indonesia's energy policy provides represents another 'window of opportunity' for the biomass gasification niche to out-compete traditional technologies. However, to date the Government's perception of justice is limited to **distributional justice** (Setyowati, 2020b). Considering only distributional justice in the formulation of energy strategy cannot guarantee that the electricity regime will become more just. On the contrary - if the Government wishes to create a more just electricity regime **it is essential to expand**

the conceptualisation of justice beyond distributional justice, to also consider recognition, due process, restorative justice, and cosmopolitan justice. These core tenets of energy justice are embedded in the energy justice framework developed by Sovacool, M. Burke, et al., 2017 - a key recommendation for the Indonesian government is to adopt an energy justice framework that allows it to more comprehensively assess and evaluate the current state, and future plans for the electricity sector. Doing so will lead to supportive policies that more accurately value the positive energy justice contribution of niche technologies like biomass gasification, and facilitate the large-scale diffusion of these niches (empowerment).

10.3 Further Research

An interesting progression of this research with high *practical relevance* would be a future-oriented STR project that utilises the findings of this historical MLP-SNM-EJ analysis. Such a project could investigate how the biomass gasification niche can be *scaled-up* - designing a number of scenarios over the short-, medium-, and long-term. A participatory approach would firstly allow actors to learn about how the niche has developed in the socio-technical context of the regime and landscape levels, and secondly engage in the design of pathways which aim to scale-up the niche. This project could unify the different actor groups working on biomass gasification and facilitate joint learning - an essential step for scaling-up the biomass gasification niche in Indonesia.

The energy justice analysis presented in this research could be greatly enhanced with several months of ethnographic research. Such a study would focus on the present, and collect data from operating projects. However due to the limited number of biomass gasification projects that are currently operating, such a study could lose some of the *practical relevance* due to the narrow scope. Another limitation of this study was on the energy justice analysis of the electricity regime - which was limited to desk research that was not comprehensive, and did not collect any primary data. A project that would have high *practical relevance*, is a large research project on energy justice and Indonesia's electricity sector.

In terms of *academically relevant* future research, it is necessary to go beyond the current *combination* of energy justice and STR theory, to investigate how these can be *integrated.* Due to the broad nature of Sovacool's ten principle framework this presents perhaps the most promising energy justice framework for this integration due to the significant overlaps it creates with the MLP and SNM frameworks.

Furthermore, this particular case study would be very interesting to investigate several other topics suggested for further research on STR (Köhler et al., 2019). In understanding transitions, there is a need to look beyond single innovations towards the interplay of competing emerging and existing technologies and these dynamics impact the system of which they are part of (Markard and Hoffmann, 2016). This approach would add interesting insights to the study of biomass gasification in Indonesia as the niche has been competing in the rural shielded areas with the solar PV and micro-hydro niches.

Researchers have also called for further investigation of the destabilization, decline and phase out of existing systems and regimes (Kungl and Frank W. Geels, 2018). This links with the need to study intensifying economic and political struggles of key actors (power) and also the study of lock-in mechanisms, how these mechanisms vary over time and how they can be overcome (Klitkou et al., 2015). Both of these research areas are particularly relevant for the study of Indonesia's electricity sector, the governance structure of which is largely responsible for inhibiting renewable energy development in the country (Bridle, Gass, et al., 2015).

A Graphs

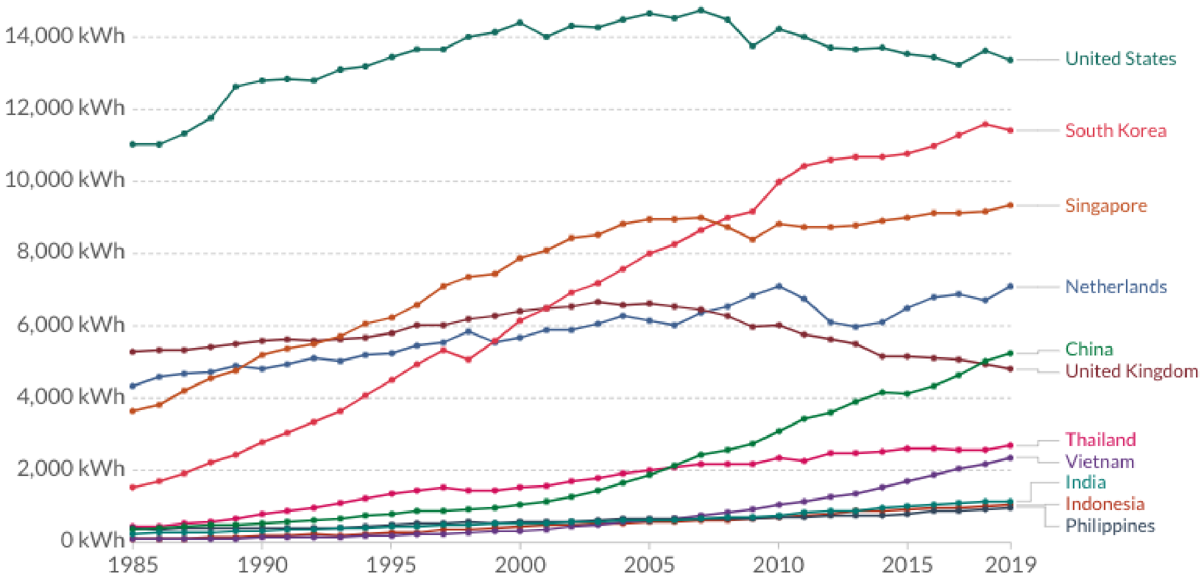


Figure A.1: Electricity consumption per capita (Source: figure from Our World in Data, 2020, data from BP, 2020).

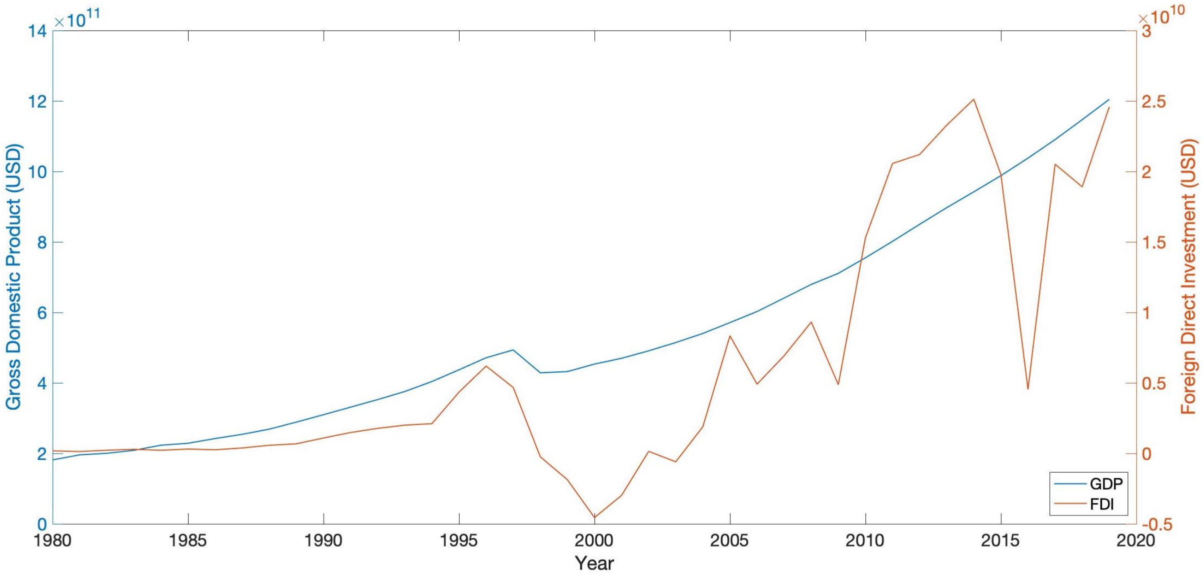


Figure A.2: Gross Domestic Product and Foreign Direct Investment in Indonesia 1980-2012 (Source: World Bank, 2020b).

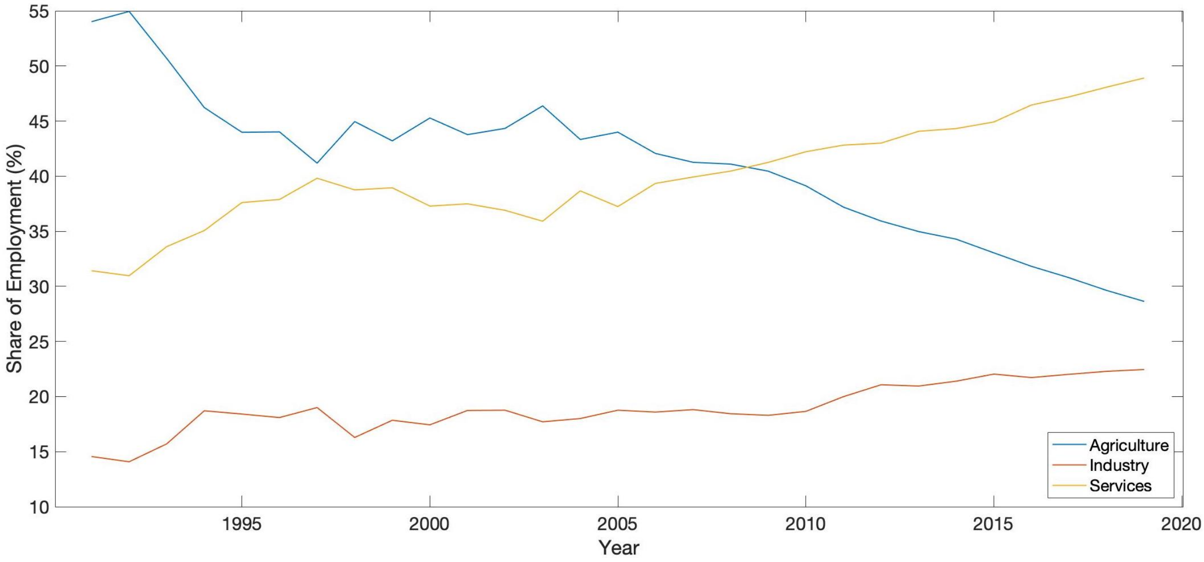


Figure A.3: Employment by sector 1990 - 2020 (Source: World Bank, 2020b).

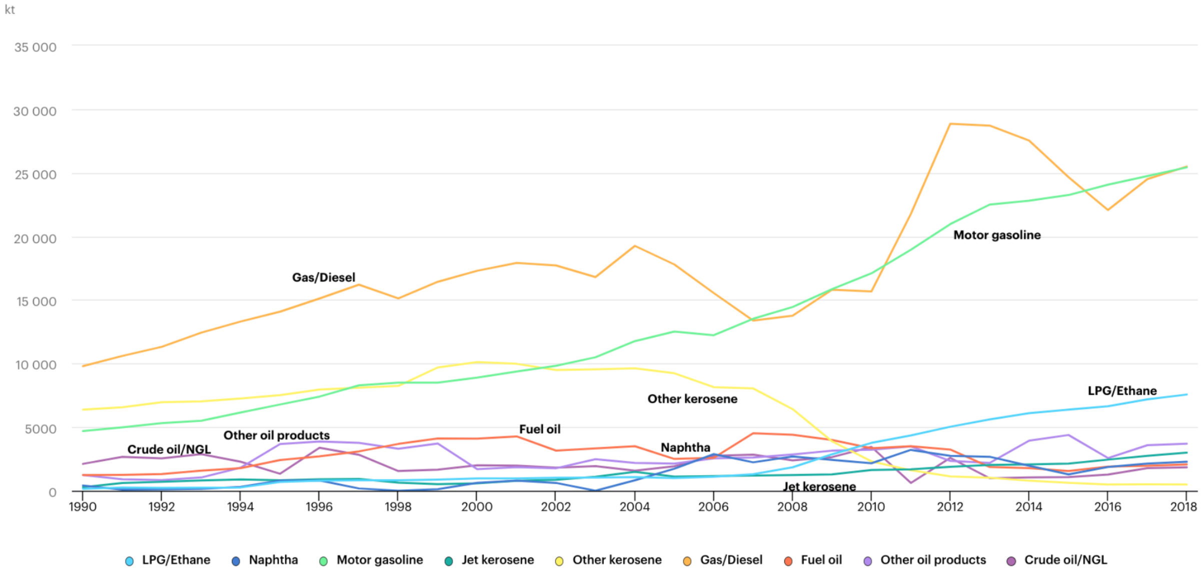


Figure A.4: Oil final consumption by product 1990 - 2018 (Source: IEA, 2020b).

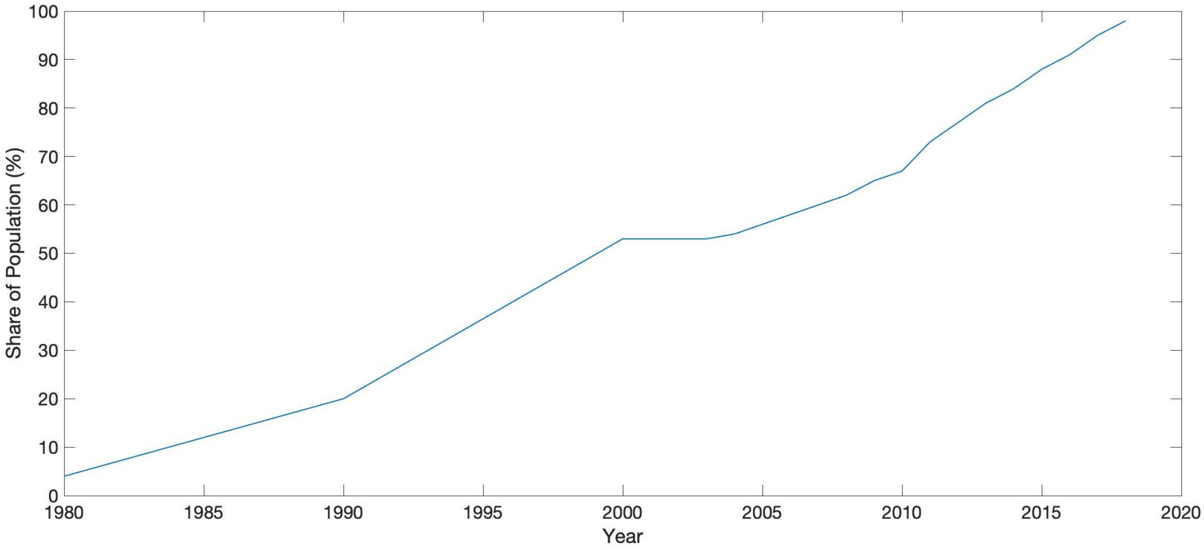


Figure A.5: Access to electricity 1980 - 2018 (Source: author, created using ADB estimates for 1980-1999 (Asian Development Bank, 2016), and IEA data for 2000-2018 (IEA, 2020b)).

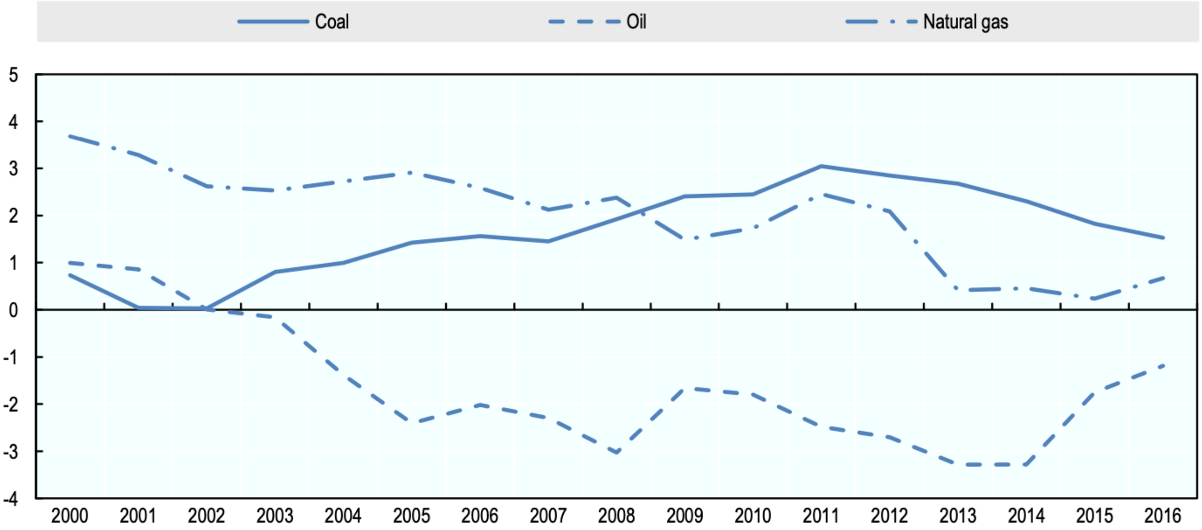


Figure A.6: Fossil fuel trade balance as a share of GDP (%) (Source: G20 Peer-Review Team, 2019).

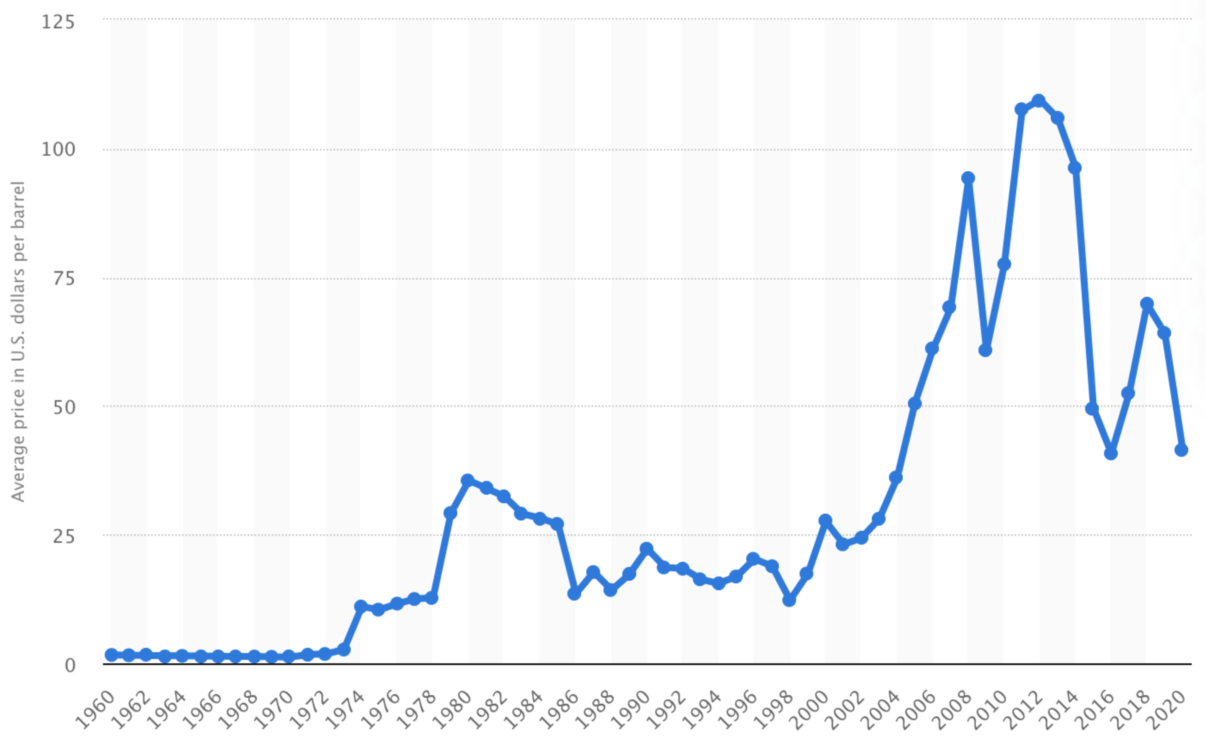


Figure A.7: Average annual OPEC crude oil price from 1960 to 2020 (Source: Statistica, 2020).

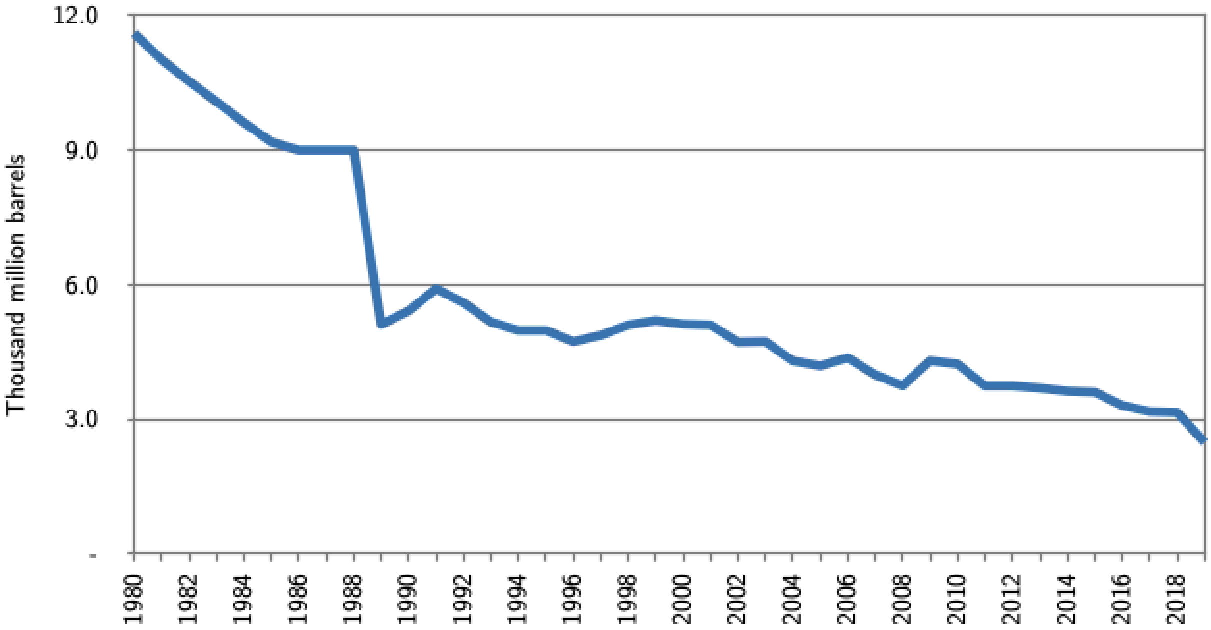


Figure A.8: Proven oil reserves 1980 - 2019 (Source: BP, 2020).

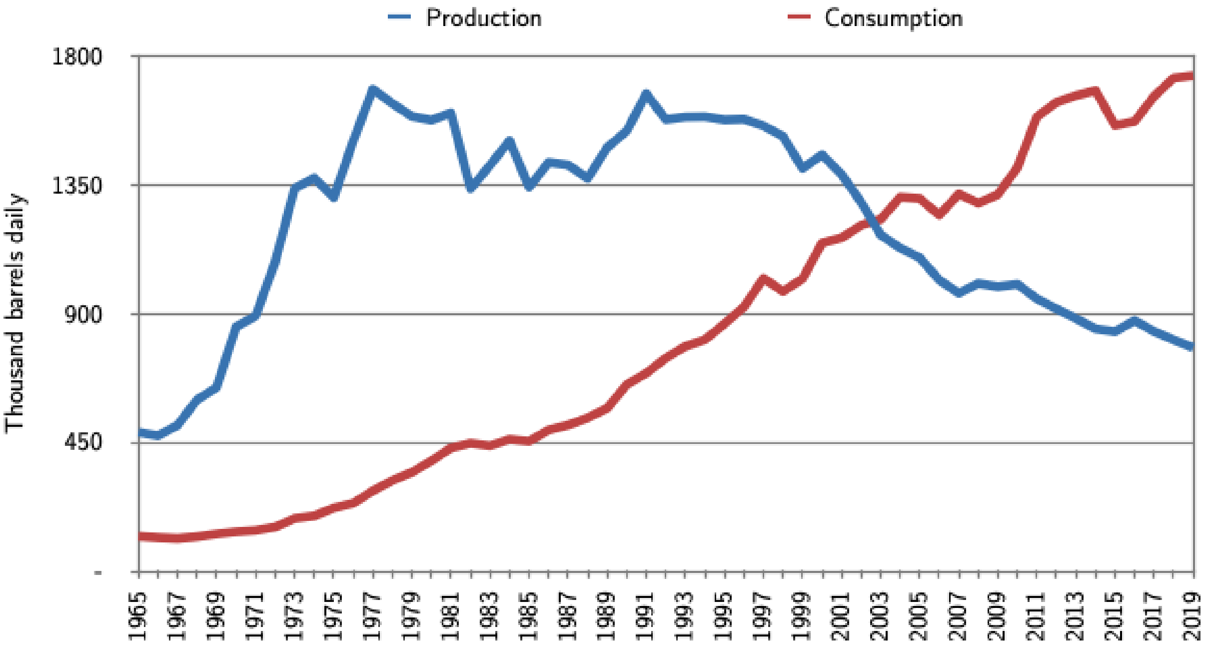


Figure A.9: Oil production and consumption 1980 - 2019 (Source: BP, 2020).

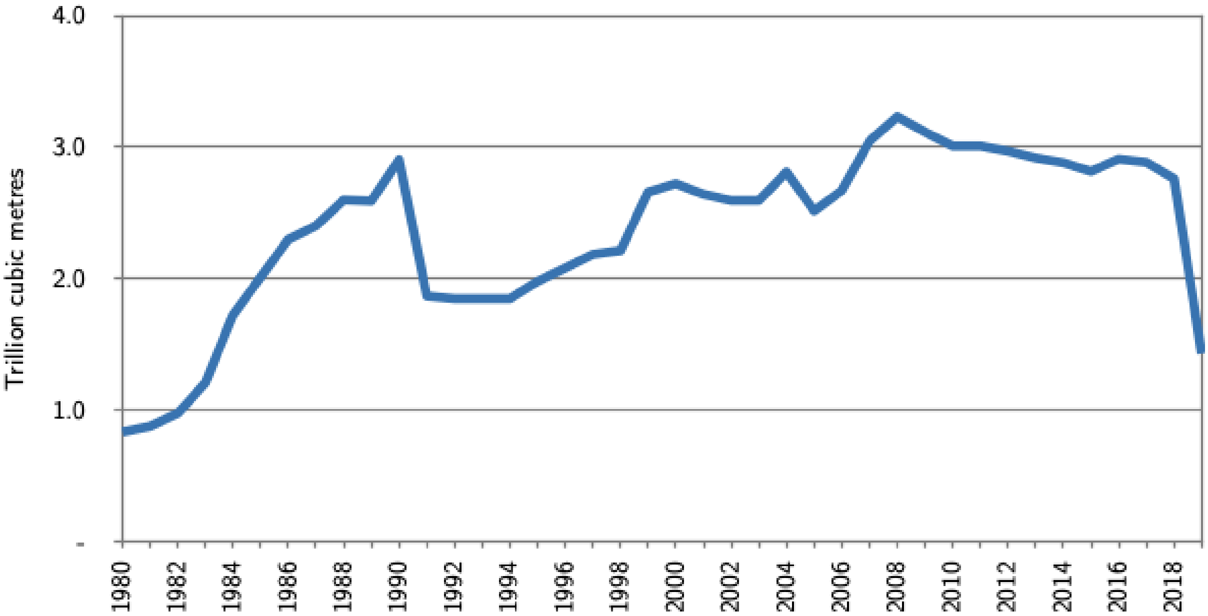


Figure A.10: Proven natural gas reserves 1980 - 2019 (Source: BP, 2020).

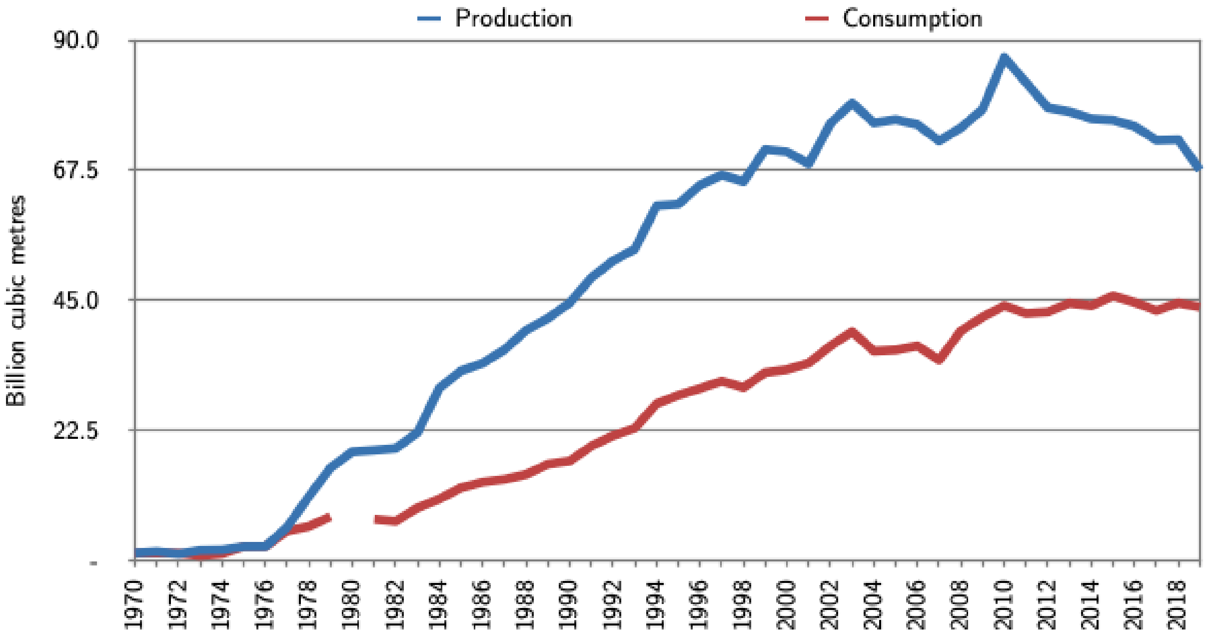


Figure A.11: Natural gas production and consumption 1970 - 2019 (Source: BP, 2020).

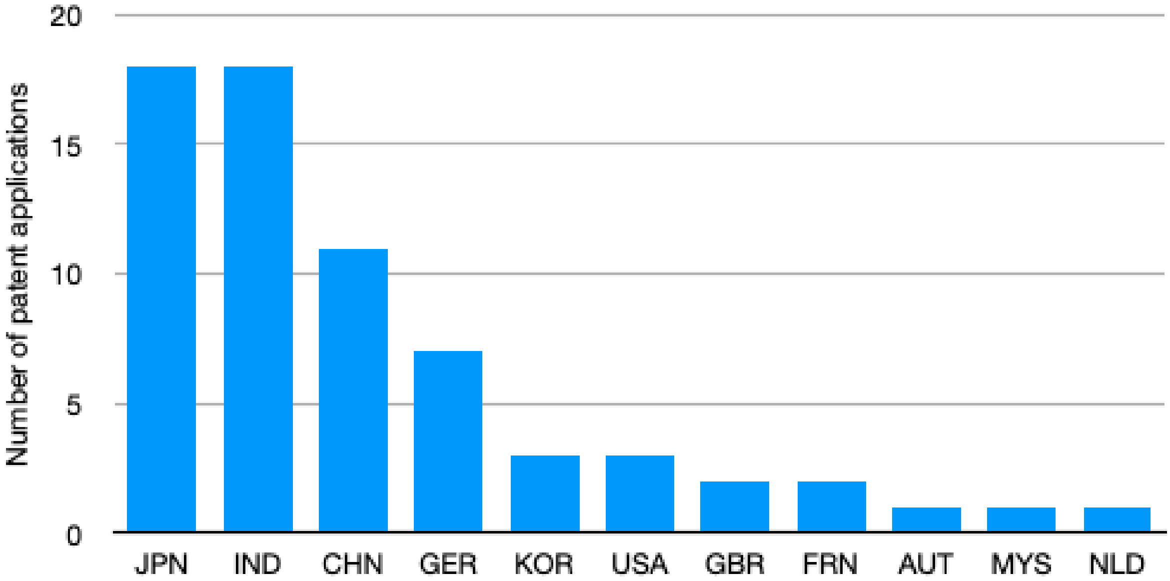


Figure A.12: Number of patent applications by country (Source: author, created using SCOPUS).

Figure A.13: The current renewable energy ecosystem in Indonesia (Source: author, adapted from Markard and Hoffmann, 2016 and pwc, 2017).

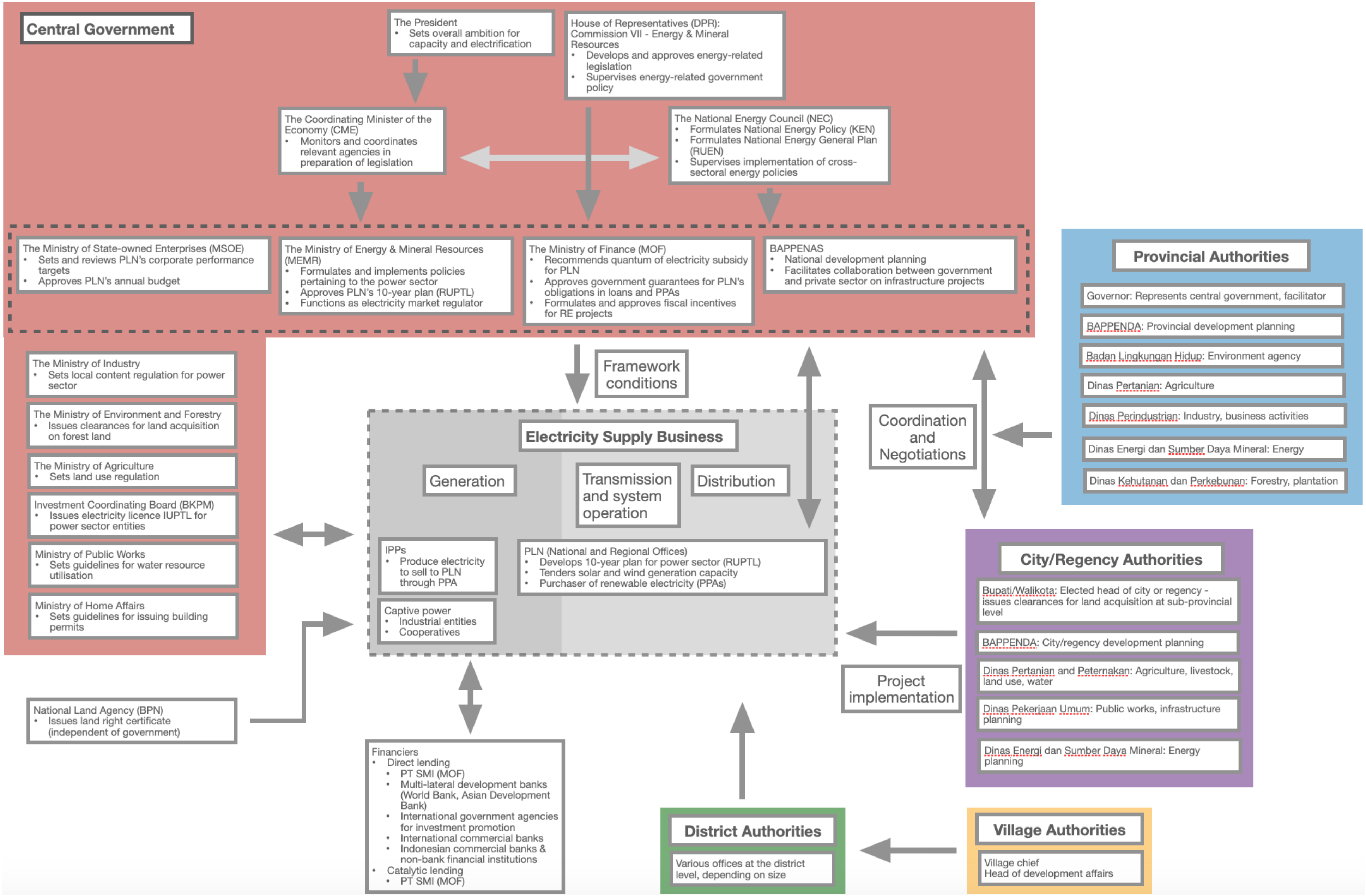


Figure A.14: PLN's average cost of generation (BPP) by location (Source: author, created using data from MEMR, 2019). The red line depicts the national BPP.

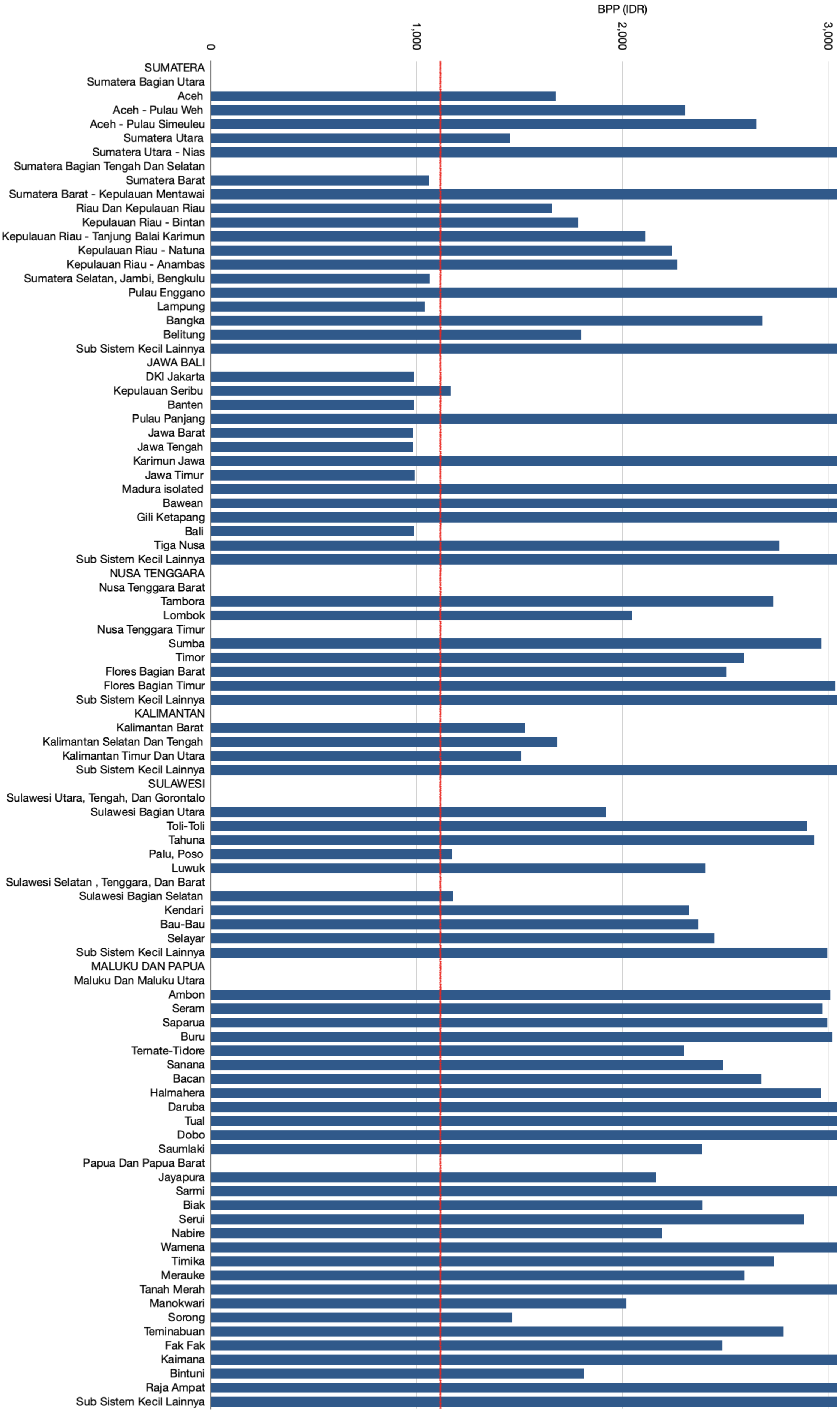
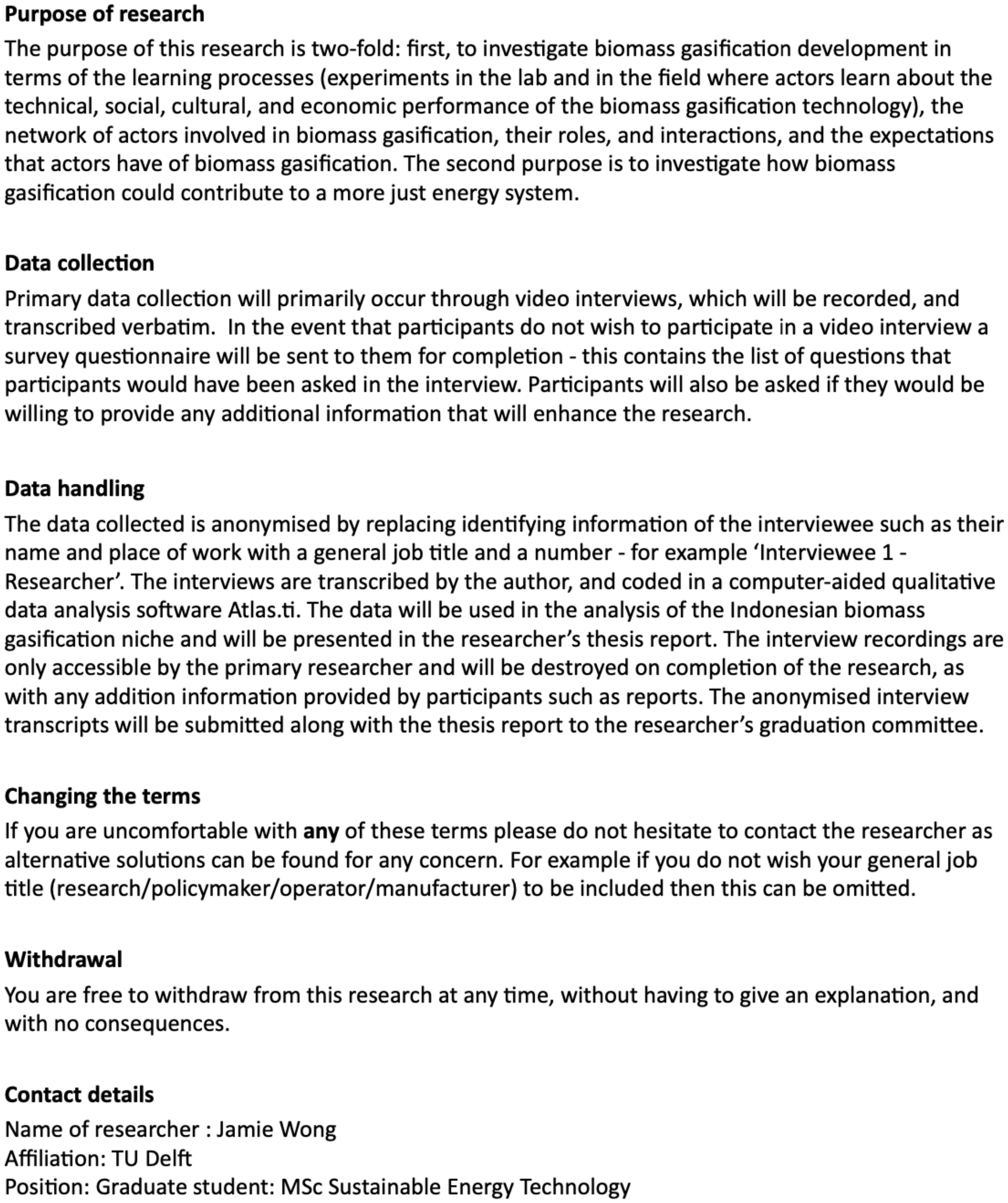


Table A.1: Biomass Potential by Province in Indonesia (Source: Primadita, Kumara, and Ariastina, 2020 - with access to MEMR database).

Province	Electrical Potential (MW)										
	Palm Oil	Sugar Cane	Rubber Wood	Coconut	Rice Husk	Corn	Cassava	Wood	Livestock	Garbage	Total
Riau	2,888		430	24	88	5	1	962	6	32	4,436
East Java		630		11	1,476	460	35	4	140	367	3,123
Northern Sumatera	1,927	30	220	5	472	111	11	4	16	99	2,895
West Java	22	62		6	1,772	90	28	4	15	558	2,557
Central Java		138		10	1,431	262	39	3	70	278	2,231
South Sumatera	1,187	43	70	3	492	10	4	91	9	62	1,971
Jambi	840		687	6	96	4	1	148	4	15	1,801
Central Kalimantan	1,234		140	4	99	1	4	18	2	10	1,510
Lampung	179	326	114	6	448	217	89	6	27	57	1,467
West Kalimantan	758		285	4	205	19	3	7	6	23	1,310
South Kalimantan	574		386	2	281	9	1	13	5	19	1,290
Aceh	646		233	3	240	13	1		17	21	1,174
East Kalimantan	837		43	1	58	2	1	5	3	15	965
South Sulawesi	25	22		5	696	119	7	18	36	33	961
West Sumatera	485		55	5	337	36	2	1	12	23	956
Bengkulu	434		108		79	11	1		4	8	645
Banten	41			3	297	3	1		2	117	464
West Nusa Tenggara				3	315	31	1	1	25	28	404
Central Sulawesi	117			11	158	18	1	1	8	11	325
Madura				3	120	90	5		32	31	281
East Nusa Tenggara				3	90	64	17	18	28	20	240
Yogyakarta		15		3	126	30	9		14	27	224
Bangka Belitung	214				3					5	222
West Sulawesi	134			2	56	5	1		3	5	206
Bali				4	131	10	1		23	22	191
North Sulawesi				15	88	45	1		4	10	163
Southeast Sulawesi	47			2	69	11	3	1	8	10	151
Gorontalo		20		3	42	54			7	4	130
DKI Jakarta					1					126	127
North Kalimantan	118										118
Papua	42			13	16	1	1	9	2	12	96
West Papua	33			1	4			12	3	2	55
North Maluku				14	9	2	1	1	2	5	34
Maluku				4	13	2	1	3	3	7	33
Riau Islands	10			1					1	3	15
Total	12,792	1,286	2,771	180	9,808	1,735	269	1,330	537	2,065	32,773

B Interview Documents

B.1 Information Sheet - Research Biomass Gasification Indonesia



Purpose of research

The purpose of this research is two-fold: first, to investigate biomass gasification development in terms of the learning processes (experiments in the lab and in the field where actors learn about the technical, social, cultural, and economic performance of the biomass gasification technology), the network of actors involved in biomass gasification, their roles, and interactions, and the expectations that actors have of biomass gasification. The second purpose is to investigate how biomass gasification could contribute to a more just energy system.

Data collection

Primary data collection will primarily occur through video interviews, which will be recorded, and transcribed verbatim. In the event that participants do not wish to participate in a video interview a survey questionnaire will be sent to them for completion - this contains the list of questions that participants would have been asked in the interview. Participants will also be asked if they would be willing to provide any additional information that will enhance the research.

Data handling

The data collected is anonymised by replacing identifying information of the interviewee such as their name and place of work with a general job title and a number - for example ‘Interviewee 1 - Researcher’. The interviews are transcribed by the author, and coded in a computer-aided qualitative data analysis software Atlas.ti. The data will be used in the analysis of the Indonesian biomass gasification niche and will be presented in the researcher’s thesis report. The interview recordings are only accessible by the primary researcher and will be destroyed on completion of the research, as with any addition information provided by participants such as reports. The anonymised interview transcripts will be submitted along with the thesis report to the researcher’s graduation committee.

Changing the terms

If you are uncomfortable with **any** of these terms please do not hesitate to contact the researcher as alternative solutions can be found for any concern. For example if you do not wish your general job title (research/policymaker/operator/manufacturer) to be included then this can be omitted.

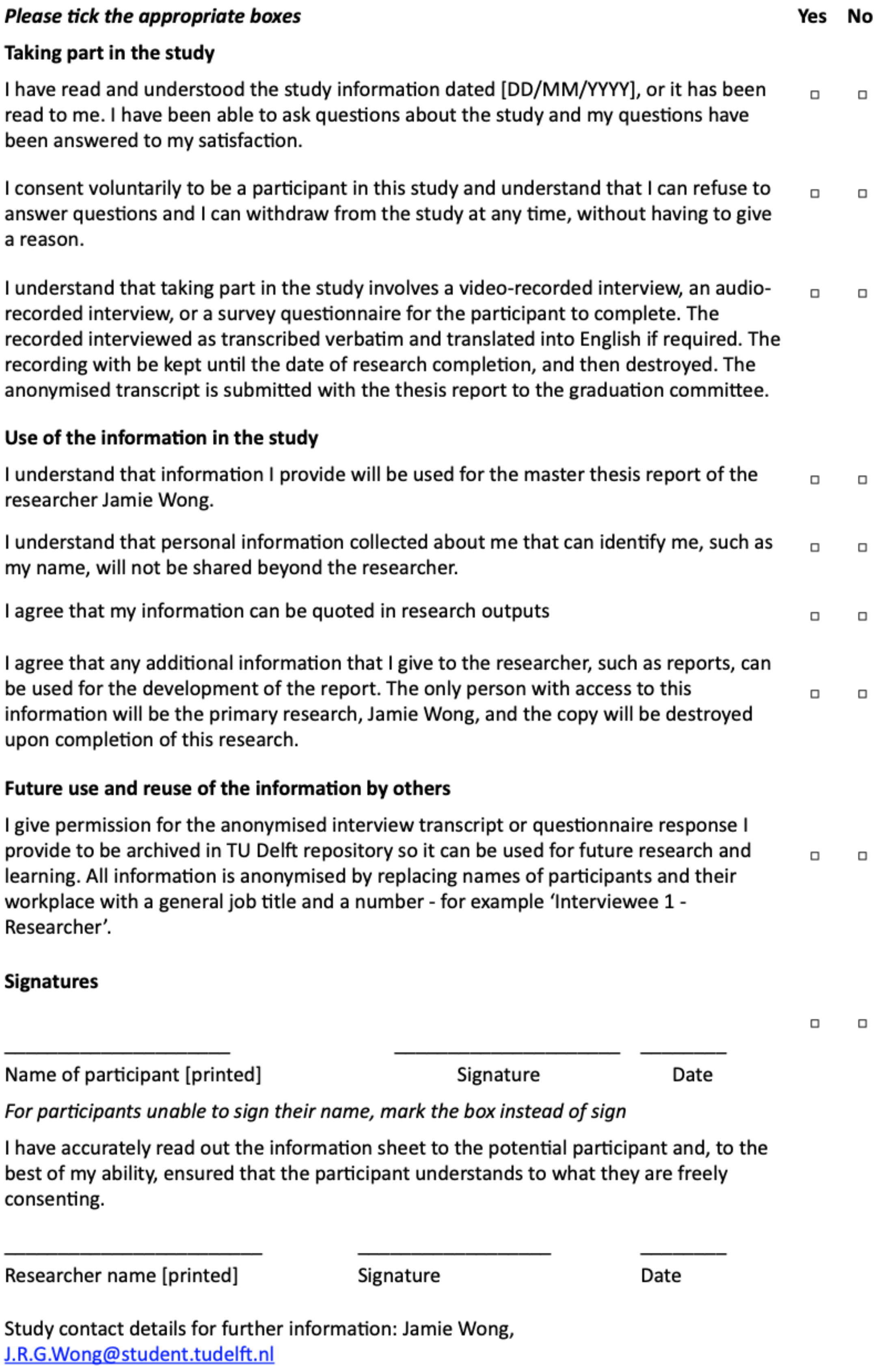
Withdrawal

You are free to withdraw from this research at any time, without having to give an explanation, and with no consequences.

Contact details

Name of researcher : Jamie Wong
Affiliation: TU Delft
Position: Graduate student: MSc Sustainable Energy Technology

B.2 Consent Form for Expert Interviews - Biomass Gasification Indonesia



Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves a video-recorded interview, an audio-recorded interview, or a survey questionnaire for the participant to complete. The recorded interviewed as transcribed verbatim and translated into English if required. The recording with be kept until the date of research completion, and then destroyed. The anonymised transcript is submitted with the thesis report to the graduation committee.	☐	☐
Use of the information in the study		
I understand that information I provide will be used for the master thesis report of the researcher Jamie Wong.	☐	☐
I understand that personal information collected about me that can identify me, such as my name, will not be shared beyond the researcher.	☐	☐
I agree that my information can be quoted in research outputs	☐	☐
I agree that any additional information that I give to the researcher, such as reports, can be used for the development of the report. The only person with access to this information will be the primary research, Jamie Wong, and the copy will be destroyed upon completion of this research.	☐	☐
Future use and reuse of the information by others		
I give permission for the anonymised interview transcript or questionnaire response I provide to be archived in TU Delft repository so it can be used for future research and learning. All information is anonymised by replacing names of participants and their workplace with a general job title and a number - for example 'Interviewee 1 - Researcher'.	☐	☐
Signatures	☐	☐

________________________ ________________________ _________

Name of participant [printed] Signature Date

For participants unable to sign their name, mark the box instead of sign

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

___________________________ _____________________ _________

Researcher name [printed] Signature Date

Study contact details for further information: Jamie Wong, J.R.G.Wong@student.tudelft.nl

B.3 Interview Questions

1. Please introduce yourself
2. Experiences with biomass gasification
    (a) Which projects have you been involved in? *Is it possible to provide a list or any documents from these projects?*
    (b) Why did your organisation/s choose to work with biomass gasification?
    (c) What were some of the key learning points from these projects? *(e.g. technical learning, social learning - organisations/workers/users, or learning about rules & regulations)?*
3. Structure of the network
    (a) Which organisations have you collaborated with? For example:
        - Project developers
        - Manufacturers and suppliers of materials and equipment
        - Designers and engineering firms
        - Finance (multi-lateral development banks, bi-lateral aid organisations, government, national banks)
        - Researchers (universities, technical institutions, R&D laboratories)
        - Public authorities (e.g. local government, regional government, national government)
        - Societal groups
        - Users (communities, industries)

    (b) Are there any organisations that are involved in biomass gasification in Indonesia that you have not mentioned above?
    (c) What are the relationships between these organisations? How are activities coordinated?
    (d) Is there any coordination between biomass gasification projects across Indonesia? Is knowledge, experience, and learning shared between projects?
    (e) Who are the main actors that drive the development of the biomass gasification technology and what role(s) do they play in its development?
    (f) What are the main regulations that have supported biomass gasification projects?
    (g) Are there any organisations or factors that inhibit the development of biomass gasification projects, or more broadly rural electrification in Indonesia? And in your view how could these be overcome?
4. Expectations of biomass gasification
    (a) How do you think the biomass gasification niche will develop?

   (b) What are your expectations of the biomass gasification technology in terms of the end-use (electricity/heat/chemicals), end-users (households/industry/other), locations (rural/cities), and how widely it will be used?
   (c) Has your expectation changed over time?
   (d) What has influenced your expectation of the technology? *(e.g. results from projects/research/reports)*

5. Energy justice
   (a) Considering the energy justice principles described in Table 2.1, how can biomass gasification contribute to a more just energy system?
   (b) Which principles should future biomass gasification projects pay closer attention to?

6. External factors
   (a) Which external factors have influenced the development of biomass gasification, or more broadly rural electrification in Indonesia? Such as the growing awareness of climate change, and commitment to transition to low carbon energy systems, financial crises, political developments, etc.
   (b) How have these external factors influenced the development of biomass gasification? *For example changes in R&D, donor activities (financing, project implementation, etc.), regulations, etc.*

7. Final remarks
   (a) Is there anything you would like to add on this topic?
   (b) With whom would you recommend we talk?

References

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