Supply Chain Management for a Policy-Led Transition from Fossil Fuels to Renewable Energy: Contributions to Indonesia's National Energy Roadmap

Satya Widya Yudha

Ph.D. Thesis

Academic Year: 2022 - 2023

Supervisor: Professor Phil Longhurst & Professor Benny Tjahjono

School of Water, Energy, and Environment

Cranfield University

This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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Abstract

The growing awareness of global warming has resulted in the need for more sustainable energy production. Facilitating the transition from fossil fuels to renewable energy sources necessitates a thorough examination of the energy sector, starting from the identification and analysis of the current energy regime, understanding the energy potentials, and ultimately moving towards the analysis of the preferred clean energy. The ultimate goal of this research is to propose comprehensive yet feasible strategies for policy recommendations as well as to facilitate and accelerate the transition from fossil fuel to renewable energy sources, by incorporating the supply chain management principle, using Indonesia's energy sector as the framework. This research is divided into a series of research starting with PESTLE and stakeholder analysis of the energy fossil sector in Indonesia and then followed by that of the renewable energy sector. Following these identifications, these stakeholders are then involved in recounting the renewable energy sector as well as determining the most suitable renewable energy in Indonesia, through qualitative approaches. In this research, geothermal energy is selected as the most suitable renewable energy in Indonesia. Following this, the research continued to illustrate the complex nature of geothermal development in Indonesia through model conceptualization by employing the System Dynamics (SD) modelling technique. The SD model visualized the whole process, elements, and stakeholders that are incorporated within the geothermal system, including some of the most important factors that can act as key enablers in geothermal development such as geothermal investment, infrastructure, upstream data, environmental aspects, incentive, pricing, permit, and public acceptance. The research is continued by employing the supply chain principles and combining them with the transition framework, through a Multi-Level Perspective (MLP). The MLP model showcases the interaction between three levels, namely the socio-technical landscape, regime, and niche innovations as well as the transition pathways from fossil fuel to renewable energy. In this study, the main keys to the transition depend heavily on many aspects such as incentives and schemes. This research provides novelties that consist of (1) MLP new data, where it is not just a framework, (2) a new method, where it selects, links, and synthesizes different methods from PESTLE, Stakeholders analysis, SD, MLP into a toolkit that can be used a reference model for other transition cases and (3) transferability, where the research is transferrable to other sustainable transition problems where policy-led development and implementation have relevance such as the digitalization of hospitals, sustainable tourism, etc. This research could be beneficial for the stakeholders and it has high credibility in terms of data source. This research is strongly relevant to international agreements that can accelerate the energy transition.

Keywords: Energy Transition, Supply Chain, Renewable Energy, Geothermal, PESTLE analysis, Renewable Energy Selection, System Dynamics, Multi-Level Perspectives, Indonesia

Acknowledgment

I have many people to thank who have supported and encouraged me through the work involved in this PhD program.

First, I have to tell that my family and I have regularly visited Cranfield since I graduated Masters in 1996, almost every two years mostly for leisure.

In 2015 I visited Cranfield as Deputy Chairman of the Energy Committee of the Indonesian Parliament to speak at CRISCOM Cranfield Indonesian Scholar Community event. This visit become a milestone in my history to fulfil my desire to further my PhD education.

Thank you to Professor Benny Tjahjono who introduced me to Professor Lynette Ryals – Pro Vice Chancellor who then encouraged me to undertake my PhD program by publication part time. This program was the first program introduced by Cranfield and is well suited for people like me who has a busy work schedule and holds a senior position within the Government. Hence, I joined the PhD program in 2016.

I therefore would like to thank my supervisors Dr Anastasios Kolios for guiding me until 2017 before he moved to another university and was then replaced by Professor Phil Longhurst, and Professor Benny Tjahjono who guided me from the beginning until the last stage of my PhD. These supervisors guided, helped, motivated and advised me throughout the program.

I want to express my enormous gratitude for all of the support, particularly during the pandemic, which has been given by my lovely family, my wife Diah Ambarsari and my three wonderful children, my daughter Dyah Roro Esti who is currently Member of the Indonesian Parliament (DPR – RI), graduated with a Bachelors' from the University of Manchester and a Masters from Imperial College London and her husband Aditya Yoga Nugraha – Manager at the State Owned Electricity Company (PLN) with a Bachelors' from the University of Indonesia and a Masters from European University Viadrina, Germany, also my Son Satya Hangga Yudha who is currently an LNG Specialist at the Indonesian Upstream Supervisory Body (SKK Migas), graduated with a Bachelors' from Michigan State University and a Masters from New York University. All of them have helped me stay focused and has embraced all my ideas even when they were very busy.

Tri Agung Soekarno, Rian Pradipta, Zainal Arifin, Mitrardi Sangkoyo, Ikbal Alamsyah who have also helped me in arranging meetings and logistics through the process in different years.

Finally, my amazing friends and family who have put up with all of this and can't wait for me to finish.

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Chapter 1: Introduction

1.1. Background

Global warming has been one of the major consequences of human activity and it is strongly related to the energy system (Giannakidis *et al.*, 2018). It is an undeniable fact that energy-related greenhouse gas (GHG) emissions have become the largest contributor to climate change, and as a result, energy systems are notably responsible for climate change (Schneider and Smith, 2009). In order to tackle this climate issue, the world's countries have agreed to limit the rise of global mean temperature to less than 2ºC with respect to pre-industrial levels (Gillet *et al.*, 2021). Known as Paris Agreement, countries around the world committed to reducing carbon emissions by ratifying the agreement. All the countries that participated set the targets in regard to carbon reduction, according to their respective capabilities, known as Nationally Determined Contributions (NDCs) (Shani and Kresnawan, 2019). The increasing awareness of global warming has led to the need for sustainable production of energy. While the energy sector has been partially contributing to the GHG emissions issues, this very sector also holds the key solutions, which involved energy efficiency and renewable energy.

For decades, Indonesia's economy has been very reliant on fossil fuel energy. While the climate crisis has been growing more important over time, a significant transformation in energy needs to take place as a priority. As part of Indonesia's international commitment to reduce its greenhouse gas emissions, as evident in its signing and ratification of the Paris Agreement, the Government of Indonesia has formulated and enacted a set of regulations and plans in order to implement a successful transition from fossil fuels to renewable energy (Reyseliani *et al.*, 2022). Compiled under a General Plan for National Energy (Rencana Umum Energi Nasional/RUEN)—a more detailed policy breakdown of Indonesia's National Energy Policy (Kebijakan Energi Nasional), regulated in Government Regulation No. 79 of 2014—Indonesia's national roadmap for energy transition is tied to its Nationally Determined Contributions within the United Nations Framework Convention on Climate Change (UNFCCC), which pledges the country to reduce its greenhouse gas emissions by 29% by 2030 (unconditional scenario), or 41% with international assistance (conditional scenario) (Santika *et al.* 2020). The renewable energy sector plays an important role to reduce carbon emissions, and Indonesia is currently aiming to increase the share of renewable energy to become 23% by 2025 within the National Energy Mix.

1.2. Research Contributions

A series of qualitative research in this thesis contributes to knowledge as it provides transferability, where it is applicable in other contexts and studies. This is particularly relevant for sectors of the infrastructure that are interlinked with political, economic, social, technological, legal, and environmental attributes. The novelties of this research arise from this work; firstly, that of new data and evidence in the field of renewable energy research for developing economies. Secondly, the development of new methods that interlinked from PESTLE, Stakeholder analysis, System Dynamic, and MLP. Finally, the approach taken is transferrable to other problem sets outside of infrastructure where the observation of policy development and implementation has relevance for many developing economies. Forexample, when specific research or analysis is intertwined with several significant aspects, such as Political, Economic, Social, Technological, Legal, and Environmental, the PESTLE analysis would be the best approach to examine these aspects effectively. Research topics that are firmly correlated with the stakeholders would require the structured involvement of these stakeholders, through several approaches, such as interviews, workshops, or focus group discussions. Another example is when a study involves identifying a number of factors that interact and affecteach other, a causal loop diagram would be the most suited approach. Lastly, when research includes the transition process that involves a number of factors from differentlevels, the Multi-Level Perspectives method to be the most-suited approach.

As one of the developing countries with many renewable energy potentials, Indonesia could be a great example for other countries that are undergoing a similar journey of the energy transition. Having known how significant the decarbonization and energy transition in Indonesia is, this series of research that has been conducted since 2017 – 2022, aims to gain a full understanding on how the energy sector works, identify the challenges and opportunities of renewable energy as the most defining factor in energy transition, and lastly formulize the most feasible strategies to achieve its decarbonization target and ultimately the energy transition itself. In terms of its practical implications, this research could be a tool to guide the country's Supply Chain transitioning energy strategies adopted by the Indonesian National Energy Council (DEN). This research offers a tool that has also been trialed and will be adopted by government institutions (e.g., Ministry of Energy & Mineral Resources, Ministry of State Planning, Ministry of Finance, Ministry of Environment & Forestry) (Chapter 9). Lastly, this research could be beneficial for policy-level scenario planning by facilitating analyses of geothermal energy and energy transition.

1.3. Thesis Structure

This thesis is structured into eight chapters: Chapter 1 provides an introduction to the study and background knowledge, including the aim and objectives of the study. Chapter 2 focuses on reviewing the literature review on supply chain and energy transition. Chapter 3 focuses on methodology, Chapter 4 focuses on a PESTLE policy mapping and stakeholder analysis of Indonesia's fossil fuel energy industry. Chapter 5 focuses on stakeholder mapping and analysis of the renewable energy industry in Indonesia. Chapter 6 focuses on stakeholders' recounts of the dynamics of Indonesia's renewable energy sector. Chapter 7 focuses on unearthing the dynamics of Indonesia's geothermal energy development. Chapter 8 focuses on sustainable transition from fossil fuel to geothermal energy using a Multi-Level Perspective approach. Lastly, Chapter 9 concludes the research by outlining a set of proposals that can accelerate the energy transition in Indonesia.

Chapter 2: Literature Review - Supply Chain Management for a Policy-Led Transition from Fossil Fuels to Renewable Energy: Contributions to Indonesia's National Energy Roadmap

2.1. Energy Transitions and Policy

The world is currently experiencing an energy milestone, one that comprises and spans social, ecological, economic, technological, and political dimensions. Energy, with its ineluctable dynamic with society and nature, has always been the essential lifeblood of a productive society and is now also the main determinant of global politics. Conflict over the mastery of energy, especially the contestation over dwindling fossil fuel reserves, has divided national interests (Brown & Hess, 2016), shaped regional and international geopolitics (Paltsev, 2016)—even instigated wars.

At a more fundamental level, faced with rising global energy consumption and demands, as well as the abject social-ecological implications of unclean energy use (such as climate change and its adverse implications), how we choose to move forward with our choices of energy usage and development will determine the survival of the planet and its future inhabitants (Adams, 2013; Delucchi & Jacobson, 2013; U.S. EIA, 2016; NOAA, 2017).[1] A solution must be found to resolve the problem of fossil fuels and their discontents in order to propel and sustain a socially and ecologically just society. A promising and imperative pathway lies in the transition from fossil fuels to renewable energy sources.

The elusive question remains: *how do we successfully transition from fossil fuels to renewable energy in a fossil fuel-dominated global economy?* For starters, the performance of renewable energy promotion in individual countries depends on a myriad of both endogenous and exogenous factors such as geography, natural resource endowment, economic wealth, industrial capacity, and global energy prices (Bayulgen & Ladewig, 2017). At a material level, an energy transition must surely involve the research, development, and implementation of advanced technology. However, such a transition does not entail an exclusively technocratic, let alone technological, approach. To do so and neglect other pressing societal factors would inevitably be counterproductive, and in the long run, would undermine the long-term aims of the energy transition itself. With far-reaching political implications—being both an inherently political commodity as well as a relation—energy necessarily requires and produces political action (Hildyard, 2016). In the context of an energy transition, Nicholas Hildyard observes that we should:

"…take the politics of technology seriously. That we do not fall into the trap of assuming that technology is neutral. That we map and understand the political

[1] In International Energy Outlook 2016, the U.S. Energy Information Administration (2016) calculates that total average world energy consumption increases annually by 1.4%. They project that this trend will continue until the year 2040.

infrastructure that supports particular technologies and the political and economic interests that benefit from them." - Nicholas Hildyard (2016).

Thus, placed in the context of the state and its infrastructural power (Mann 1984), the policy becomes a crucial political springboard and is as much a requisite for a successful and holistic energy transition as, say, the scientific development of cleaner energy and power generation technologies using renewable energy sources. Bayulgen and Ladewig (2017) stress that:

"Governments have policy tools that can incentivize the production and consumption of energy from renewable sources. Even though the exact combination of policies varies from one country to another, policy promotion makes a difference in the renewable energy performance of countries." - Bayulgen and Ladewig (2017)

As a concrete example, the results of a study conducted by Ogihara et al. (2007), based on 28 case studies in India, China, and Thailand, strongly support and confirms three significant hypotheses: first, policies that help to create a level playing field in energy markets for renewable energy to compete with fossil fuels will hasten the widespread adoption of renewable energy; second, the creation of public and private institutions that provide increased financial and technical support will promote development and marketing of renewable energy and thus help to hasten its widespread adoption; and third, in developing countries, the initial focus of policies should be on promoting renewable energy in non-grid-connected areas.

In a wider global context, the upsurge of international consciousness and commitment to the urgency of sustainable energy use is indeed manifest and can be confidently measured, in national policy changes following decades of UN-led negotiations and conventions on climate change.[2] Currently, various UN-member nations have implemented national roadmaps for energy transitions to renewable energy, including Indonesia with its General Plan for National Energy (Rencana Umum Energi Nasional/RUEN) (DEN, 2016). REN21's Renewables 2016 Global Status Report identifies renewable energy policies in 146 countries by the end of 2015. Also, as of year-end 2015, renewable energy targets had been found in 173 countries at the national or state/provincial level (REN21, 2016). Furthermore, regional commitments have already begun to be consolidated, as in the case of the European Union with its long-term objective of 27% of final energy consumption by 2030, followed by regional organizations in Africa (ECOWAS) and the Caribbean (CARICOM).

These national and regional roadmaps take into account the major relevant factors needed to progress, such as technology development, market incentives, and legal frameworks. However, one underemphasized yet pivotal field is the supply chain management needed to bring an energy transition to fruition. It is this lacuna in energy policy that this study intends to fill and expand upon, in the specific context of Indonesia's national energy roadmap. It is hoped that a comprehensive supply chain

[2] For an overview and timeline of UN climate conventions, see the United Nations Framework Convention on Climate Change Calendar

management program for a transition from fossil fuels to renewable energy will provide a significant contribution, not merely to academia, but foremost to the future architecture of Indonesia's energy policy.

In addition, looking at lessons learned from Indonesia's intricate oil and gas supply chain framework, there is an imperative to develop a more streamlined and simplified supply chain that would attract and incentivize all related stakeholders to play their part in bringing Indonesia's energy transition to fruition.

2.2. Indonesia's Renewable Energy Policy: the General Plan for National Energy

As part of Indonesia's international commitment to reduce its greenhouse gas emissions, as evident most recently in its signing and ratification of the Paris Agreement, the Government of Indonesia has formulated and enacted a set of regulations and plans in order to implement a successful transition from fossil fuels to renewable energy. Compiled under a General Plan for National Energy (Rencana Umum Energi Nasional/RUEN)—a more detailed policy breakdown of Indonesia's National Energy Policy (Kebijakan Energi Nasional), regulated in Government Regulation No. 79 of 2014—Indonesia's national roadmap for energy transition is tied to its Nationally Determined Contributions within the United Nations Framework Convention on Climate Change (UNFCCC), which pledges the country to reduce its greenhouse gas emissions by 29% by 2030 (unconditional scenario), or 41% with international assistance (conditional scenario).

The General Plan for National Energy aims to push forward Indonesia's energy independence and energy security (DEN, 2016). This is further broken down into the six primary points of the General Plan, namely:

1. Energy Efficiency and Conservation of Energy and the Environment
2. Development of Energy Infrastructure
3. Energy as Capital for Development
4. Development of New and Renewable Energy
5. Synchronization of Fiscal Targets with Energy Policy
6. Proficiency of Technology and Increasing Added Value

When scrutinized, the General Plan for National Energy generally neglects and/or lacks a comprehensive supply chain management analysis and approach for fulfilling its ambitious targets and tackling the issues related to renewable energy development in Indonesia. In addition, data from the Final Report of the Task Force for Accelerating the Development of New and Renewable Energy and Energy Conservation (KESDM 2016) shows that, despite contextual differences between each type of renewable energy, there are a number of general problems that inflict the entire sector as a whole, namely:

a. Tariff: expensive NRE power plants are unaffordable for the National Electricity Company (PT PLN);
b. Licensing: licensing processes are unduly lengthy and complex, especially for

geothermal projects which are generally located in forested areas;

c. Data: there is a lack of data and information on NRE;
d. Regulations: there are underdeveloped regulations and standards specific to NRE investment;
e. Electricity Trading Regulation (PJBL): no PJBL standard for renewable energy;
f. Financial institutions funding: lack of capacity and interest of local financial institutions in financing renewable energy projects.

2.3. Definitions, Scope, Aspects, and Issues of Renewable Energy Supply Chains

Renewable energy can be broadly defined as: "*a free source of sustainable energy, such as wind or solar energy that produces no negative impacts during [the] conversion process like the emission of hazardous substances*" (Wee et al., 2012, p. 5452). Cucchiella & D'Adamo (2013) further elaborates on renewable energy as:

"...a resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric [energy]), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). [Renewable energy] does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources." - Cucchiella & D'Adamo (2013).

In a more systematic fashion, Belessiotis & Delyannis (2000) categorize renewable energy sources into direct solar energy, geothermal energy, hydropower, wind energy, tidal energy, wave energy, Ocean Thermal Energy Conversion (OTEC), biomass, and refuse.

Renewable energy sources possess benefits such as social and economic development, land restoration, reduced air pollution, abatement of global warming, fuel supply diversity, and also reduced risks of nuclear weapons proliferation (Johansson et al., 1992). However, despite its ostensible advantages, power generation through renewable energy sources is not without its own potential negative social-ecological implications, and thus must be managed with best practices and in compliance with internationally recognized social and ecological standards.[3]

[3] Wee *et al.* (2012) lists the potential social-ecological impacts of renewable energy sources, as follows: hydrogen can potentially incur thermal and chemical changes in the atmosphere, ozone depletion, can influence microorganisms in the soil and water and incur accelerated corrosion of manmade structures; wind can have impact on landscape change, soil erosion as well as reduced air circulation and deterioration of local air quality; solar energy can have impact on landscape change, soil erosion and reduced solar irradiation for plants and vegetation; hydropower can have incur change in local ecosystems and local weather conditions, can be induction for earthquakes as well as incur social and cultural impacts; geothermal energy can have impact on landscape change, underground water resources and accelerated cooling of the earth's core; tidal/wave energy can incur landscape change, reduced water motion/circulation and deterioration of local water quality; biofuels may release global warming-inducing gases such as methane during their production, as well as incur landscape change and deterioration of soil productivity; nuclear energy may incur radiation leakage and contamination, as well as necessitate the disposal and safe storage of nuclear waste for hundreds up to

thousands of years in geological repositories.

Challenges in developing renewable energy encompass project economics, technical constraints, supply chain capacity, social effects, namely amenity and aesthetics, and environmental impacts (Cucchiella & D'Adamo, 2013). Furthermore, Wee et al. (2012) emphasize that further development of renewable energy entails the involvement of government and research institutions, commoditization of renewable energy sources, the realisation of renewable energy value, improvement of distribution networks as well as the development of advanced storage technology.

Apart from renewable energy, this study will also incorporate the theory and practice of supply chain management. Cucchiella & D'Adamo quote Askin & Goldberg in broadly defining supply chains and supply chain management as follows:

"The supply chain encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain. Supply Chain Management is the integration of these activities through improved supply chain relationships to achieve sustainable competitive advantage." (Cucchiella & D'Adamo, 2013).

Coupled with the extensive field of supply chain management, renewable energy has since produced its own disciplinary niche. In general, a renewable energy supply chain functions in two major sectors, namely the utilization and distribution of renewable energy sources (Wee et al., 2012). Figure 1 shows a purely renewable energy supply chain process. Conceptually, one form of supply chain management applied to renewable energy is Green Supply Chain Management (GSCM), used interchangeably with Environmental Supply Chain Management (ESCM). At a more complex level is Sustainable Supply Chain Management (SSCM) and Figure 1 illustrates an example of the complexity of biomass energy SCM. Whereas GSCM/ESCM considers how supply chain management can be viewed in the context of the environment, SSCM expands its scope to encompass social and ethical issues (Cucchiella & D'Adamo, 2013).

There is a wide range of stakeholders involved in a renewable energy supply chain. In general, these stakeholders consist of international investors/donors, national politicians and policymakers (including legislators and governors), public services institutions (ministries of health, social security agencies and ministries of finance), scientific researchers, renewable energy investors and commercial players, labor (unions, medical associations), commercial/private for-profit organizations, nonprofit (nongovernmental) organizations and foundations, civil society, as well as the public (users/consumers) (Wee et al., 2012). Stakeholder analysis for a specific Indonesian context will be discussed in further documents.

In a supply chain context, stakeholders can be categorized according to four distinct links in the supply chain process, namely supply, production, distribution and demand. In the supply sector, stakeholders comprise scholars/researchers, investors of substitute energies, nonprofit/nongovernmental organizations (NGOs), civil societies and the general public. These stakeholders deal with discourse and issues such as Governmental policy, location selection, land usage, fewer substitution effects and sustainability.

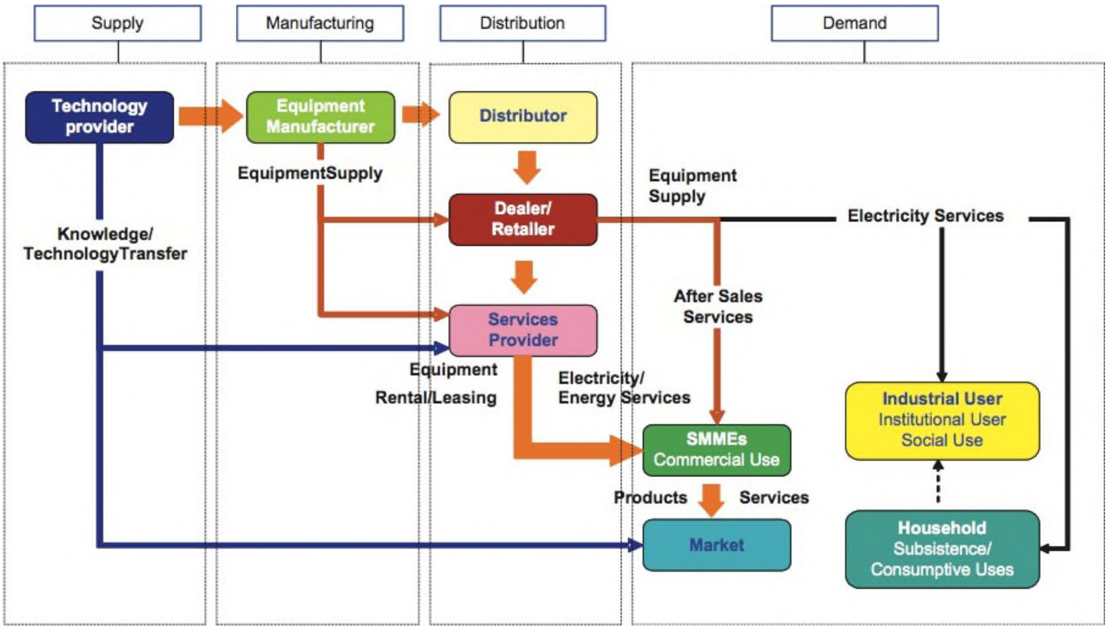

Figure 1. A pure renewable energy supply chain process. Source: Wee et al., 2012, p. 5456.

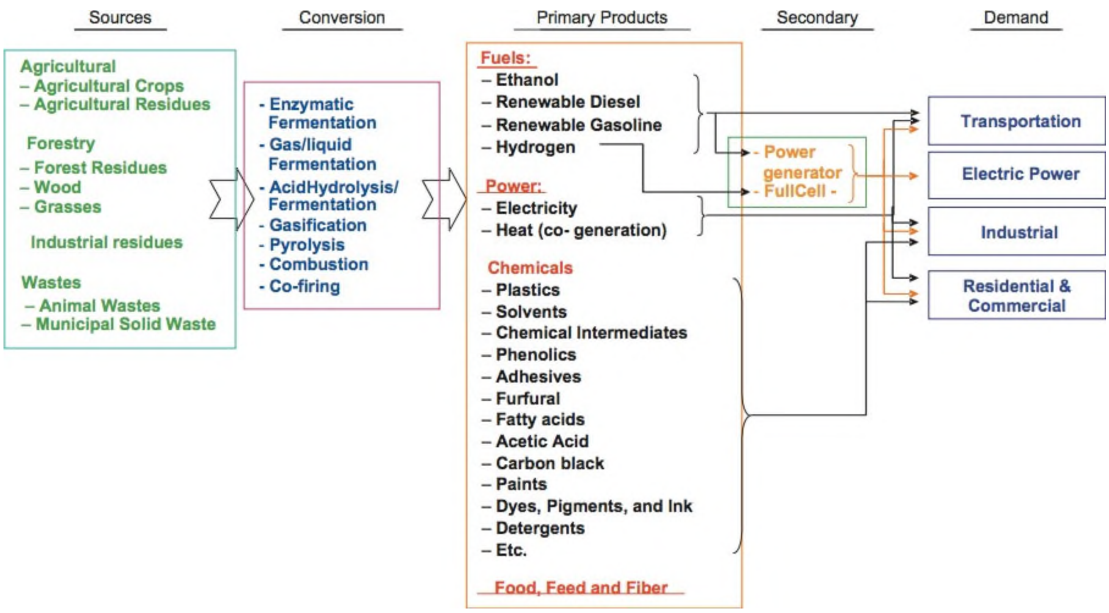

Figure 2. Example of biomass energy flows. Source: Wee et al., 2012, p. 5453.

In the production sector, stakeholders comprise scholars/researchers, investors, civil society and labour. These stakeholders deal with more technical discourse and issues such as conversion efficiency, stability supplement, cost reduction-operations & maintenance, government policy, financial aid, less environmental impact and fuel cell technology.

In the distribution sector, stakeholders comprise commercial actors, civil society, distributed grid operators, storage providers and information system managers.

These stakeholders deal with discourse and issues such as distribution efficiency, balance in demand, storage, usage information and distribution grids. The demand sector has stakeholders comprising the local population (users/consumers), policymakers, substitute energy players, NGOs, civil society and international donors. These stakeholders entail discourse and issues such as emission pollution, affordable cost, continuous supply, employment, education as well as storage and resale.

2.4. Recapitulation of Knowledge Gap

There is limited author that covers three things namely Transition, Supply Chain, Renewable. At an academic level, literature on renewable energy and supply chains has experienced a rise since the early 2000s, yet still leaves ample room for further inquiry (Figure 3) (see Appendix 2A). Cucchiella & D'Adamo, (2013) comprehensively notes and analyzes that from 2003 to 2013 as many as 104 papers (consisting of 47 scientificjournals, 13 proceedings of scientific conferences and 9 scientific reports) were published globally related to renewable energy and supply chains. Geographically, the USA is the major contributor with 27 papers (26%), followed by European (59%) and Asian states (12%).

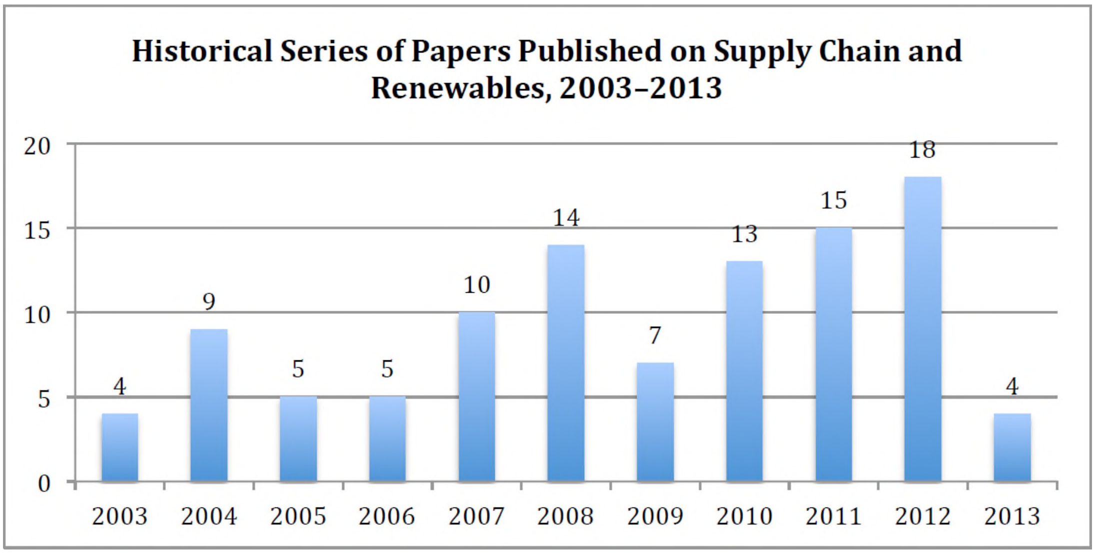

Figure 3. Historical Series of Papers Published on Supply Chain and Renewables from 2003 to 2013. Source: Adapted from Cucchiella & D'Adamo (2013).

Methodologically, 63 papers use a qualitative approach, whereas 21 use a quantitative approach and 20 use a mixed approach (Figure 3). 75% of all qualitative papers (62 papers) employ relevant case studies. 39% of quantitative and mixed studies employ relevant mathematical models, whereas 37% employ hybrid combined models. Based on the prominent perspectives utilized, 20 papers focus on a methodological outlook, 15 papers on the environment, 14% on politics, 14% on technology, and 12% on economics while 29 papers include several outlooks at once.

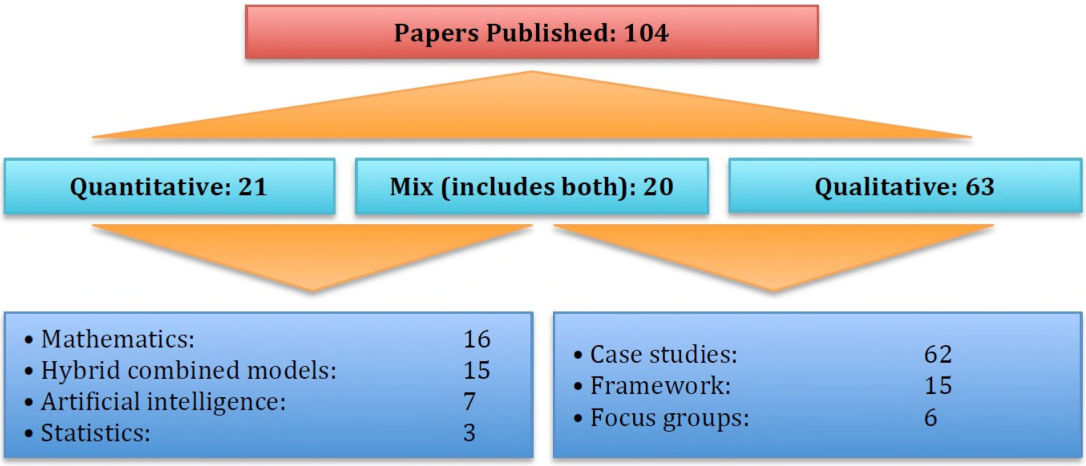

Figure 4. The classification of research papers published. Source: Adapted from Cucchiella & D'Adamo (2013).

Based on the specific types of renewable energy studied, 45 papers discuss bioenergy sources, 27 papers discuss energy in general, 8 papers discuss a renewable energy framework, 6 papers discuss wind and solar photovoltaic sources respectively and 4 papers discuss hydrogen and raw materials respectively (Table 1). Furthermore, in regard to particular aspects of the supply chain, only 15% of papers specifically analyze logistics and design.

Table 1. Matrix of Subject Matter of Precedent Literature, 2003–2013. Source: Adapted from Cucchiella & D'Adamo, (2013).

Research perspectives of papers published		**The topical focus of publications**		**The focus on specific types of renewable energy**	
Economic	12	Management	6	Raw Materials	4
Technological	14	Technology	6	Hydrogen	4
Political	14	Environment	9	Solar PV	6
Environmental	15	Chemistry	13	Wind	6
Methodological	20	Renewables	20	Framework	8
Mix (includes several perspectives)	29	Energy	34	Energy	27
				Bioenergy	45

In complement to Cucchiella and D'Adamo's findings, we find that from 2014 to March of 2017, an additional 53 scientific and academic journal articles have been published that address renewable energy vis-à-vis supply chains (Figure 5): 16 papers in 2014, 12 papers in 2015, 20 papers in 2016, and 5 papers in March of 2017. However, in line with Cucchiella and D'Adamo's previous findings, these articles are highly technical in nature and mostly specifically address biomass and biofuel supply chains.

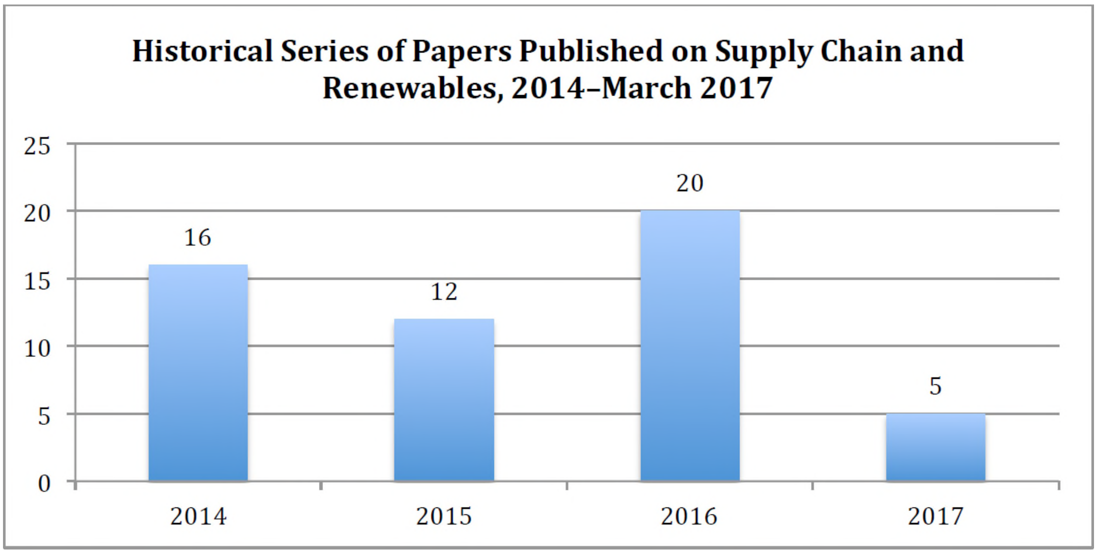

Figure 5. Historical Series of Papers Published on Supply Chain and Renewables from 2014 to March 2017

Only 8% of these 53 articles employ a more holistic outlook on the specific context of policy-led energy transitions.[4] In terms of the specific type of supply chain analyzed, 36 out of 53 papers (68%) focus on biomass and biofuel supply chains, whereas the remaining are scattered in hydro, photovoltaic, wind, and waste, or address non-specific types of renewable energy (Table 2).

Table 2. Matrix of Subject Matter of Precedent Literature from 2014 to 2017

The topical focus of papers published	
Biomass and Bioenergy supply chains	36 (68%)
Other types of renewable energy	13 (25%)
Policy-based analysis	4 (8%)
Total	53

The rise of published scientific and academic papers on renewable energy and supply chains reflects a growing international interest and consciousness of the necessity of a supply chain-based approach toward an energy transition. However, many of these papers do not specifically address a policy-led approach. Therefore, based on data from precedent scientific articles on renewable energy and supply chains, there is substantive room for research and inquiry in the context of facilitating correct policy, especially in the aforementioned underrepresented fields. In short, there is a gap of knowledge in precedent literature concerning a policy-led supply chain management approach to a renewable energy transition.

[4] Just 4 out of 53 articles specifically address policy *vis-à-vis* a supply chain strategy in the context of renewable energy: (1) Simoes, S., Huppes, G., Seixas, J. (2015) 'A Tangled Web: Assessing overlaps between energy and environmental policy instruments along the electricity supply chain'; (2) Lin, C.K., Moffat, P.A. (2017) 'Global Supply Chain under the Paris Agreement: The Relevance of Chemical and Product Regulations'; (3) Vermeulen, W.J.V. (2015) 'Self-Governance for Sustainable Global Supply Chains: Can it Deliver the Impacts Needed?'; (4) Hoggett, R. (2014) 'Technological scale and supply chains in a secure, affordable and low carbon energy transition'.

Ultimately, in this series of research, particularly in Chapter 8 (Paper 5), the policy-led supply chain aspects were addressed to fill in the knowledge gap, as it complements the previous research by Geel (2016). This chapter proves that the framework provided by Geel (2016) is not just a framework for explaining the transition process, but it can be developed to explain the supply-chain processes and their position and roles in the transition. This series of research is firmly constructed and based on data and information that are obtained mostly from prominent stakeholders, which makes its validity also prominent thus its strength. In order to adopt the research framework, it would require similar approaches. Therefore, should the data and information be lacking, the research approach should be paired up with probability analysis hence its weakness.

2.5. Conclusion

Faced with rising levels of consumption and demand in global energy use, coupled with the significant adverse effects of fossil fuel-based energy generation and use, a potential and promising pathway to a clean and sustainable future lies in the transition from fossil fuels to renewable energy. Such a transition necessarily entails strong and well-coordinated policy frameworks, both at the national as well as regional levels. National coordination and international cooperation are of utmost importance in fulfilling this ambitious yet urgent aim. Hundreds of countries have now implemented and set medium-to long-term targets for emission reduction as well as support for renewable energy.

However, existing policy frameworks as well as precedent academic literature show critical negligence or underdevelopment of one crucial aspect required for a successful energy transition, namely a supply-chain management approach. Therefore, placed in the context of Indonesia—the world’s largest archipelago and a country that is one of the most vulnerable to the adverse effects of climate change and global warming—this study aims to address the pressing issue of a policy-led supply chain management approach to a transition from fossil fuels to renewable energy. It is hoped that this study can contribute not only to academia but also to a direct influence on national state policies in the energy sector.

Chapter 3: Methodology

Facilitating the transition from fossil fuel to renewable energy sources in Indonesia requires a comprehensive analysis of Indonesia's energy sector, which would need to answer some of the research questions:

- What is the current energy regime in Indonesia? (including fossil fuel and renewable energy)
- What is the most suitable renewable energy in Indonesia?
- What are the dynamics of the selected renewable energy in Indonesia?
- What are the strategies for Indonesia's energy transition that involves the selected renewable energy?

To understand the complexity of the energy transition, this article will formulate several objectives as a guide to a series of researchregarding Indonesia's energy transition. These objectives are shown in Table 3.

Table 3. List of Research Objectives

Objective 1	Identifying risks and stakeholders of fossil fuel energy in Indonesia;
Objective 2	Identifying risks and stakeholders of renewable energy in Indonesia;
Objective 3	Reviewing key enablers and barriers for the transition to renewable energy and selecting the type of renewable energy to focus on;
Objective 4	Analyzing the supply chain aspects for the chosen renewable energy in Objective 3;
Objective 5	Analyzing the role of the chosen renewable energy in the context of the energy transition;
Objective 6	Identifying the dynamic elements of the chosen renewable energy;
Objective 7	Propose policy recommendations to enhance the development of the chosen renewable energy.

Despite the growing number of published scientific and academic papers on renewable energy and supply chains, many of these papers do not specifically address a policy-led approach (will be discussed further in Chapter 2 – Literature Review). Consequently, there is a gap of knowledge in precedent literature concerning a policy-led supply chain management approach to a renewable energy transition. The ultimate goal of this research is to propose comprehensive yet feasible strategies to facilitate and accelerate the transition from fossil fuel to renewable energy sources in Indonesia. Seven main objectives were formulated and used as a guide for a series of research to be conducted. In this section, the research approach for each of the objectives will be explained. Figure 6 illustrates the research sequence of the research, starting from the literature review, the specification of each objective, from Objective 1 to Objective 7, and the papers published as the products of this series of research.

The series of research begins with understanding the current energy regime in Indonesia, which is fossil fuel energy. This research mainly focuses on Objective 1, which is identifying risks and stakeholders of fossil fuel energy in Indonesia. The approach adopted in the research follows the so-called PESTLE analysis (based on

Mytilinou et al. (2017)), a frameworkor tool typically used in business and management to analyze the environment they areoperating in or are planning to launch new operations in or monitor the macro-environmental (external) factors that have an impact on that environment. PESTLE analysis consists of the following individual components: political, economic, social, technological, legal, and environmental, hence PESTLE. It is expected that this framework will facilitate an understanding of the dynamics of the problem, and it could be used to provoke further research directions.

Following the research on Objective 1, the research continues with understanding the energy regime that Indonesia is planning to move forward with, which is renewable energy. This research revolves around Objective 2, which is identifying risks and stakeholders of renewable energy in Indonesia. This research aims to identify the obstacles and unearth the inner workings of the implementation of the distribution of renewable energy, by enacting a PESTLE policy mapping and stakeholder analysis. The main goal is to dissect and analyze the specific relationships of interest within Indonesia’s renewable energy sector and holistically approach the need to adequately cover all relevant terrain in the renewable and sustainable energy sector. This is done by observing agencies or institutions, involved parties, and all relevant stakeholders in the industry with an ultimate goal to better elucidate the various points of dispute among stakeholders and thus come to a recommendation for institutional actors as to how to better promote renewable energy in Indonesia. Similar to Objective 1, the research on Objective 2 also employed the PESTLE analysis for its approach.

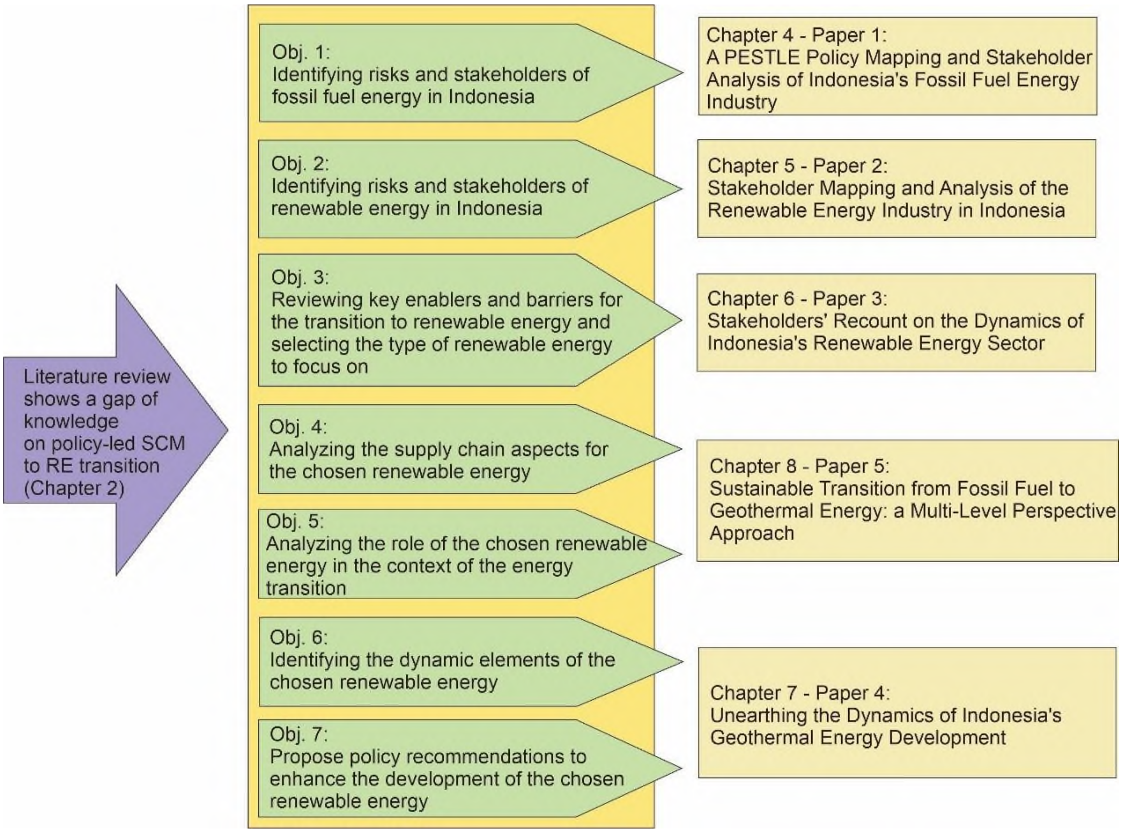

Figure 6. Diagram of research's sequence from literature review, objectives specification, and the papers resulted

After the PESTLE analysis on both fossil fuel energy and renewable energy, a further literature review was conducted to identify the academic literature coverage as well as the gap in knowledge pertaining to the renewable energy sector. Following the literature review, the research continues which focuses on Objective 3, which is Reviewing key enablers and barriers to the transition to renewable energy and selecting the type of renewable energy to focus on. This research employed a qualitativeapproach based on a Focus Group Discussion (FGD) as a primary research method (based on Kvale (1996)), complemented by the document analysis. The participants were chosen due to their expertise and experience in renewable energy development in Indonesia. Their representation encompasses the collective view of stakeholders identified in the previous research on Objective 2, cutting across the political, economic, social, technological, legal, and environmental (PESTLE) aspects of renewable energy development in Indonesia.

Following the research on Objective 3, the next course of the research focuses on analyzing the selected and most suitable type of renewable energy according to the previous research, which is geothermal energy. Geothermal energy development is a complex and dynamic system involving stakeholders, institutions, regulations, technologies, and other interconnected and changing elements. To provide a sufficient understanding of the complexity of geothermal development, a holistic and systematic approach is required. Understanding the relationships between the elements involved in geothermal development is becoming increasingly important and useful in developing a long-term strategy to boost geothermal energy development. In order to gain a more holistic, comprehensive, and dynamic perspective, it is necessary to solicit and analyze some critical information directly from the stakeholders in the geothermal sectors in Indonesia. The particular research is employing the semi-structured, in-depth interview method, involving a large number of key stakeholders in geothermal energy in Indonesia, to identify the key elements that play critical roles in the geothermal energy sector. The interviews were conducted in Indonesian, audio recorded, transcribed, and then translated into English. A qualitative data analysis tool was used to code the interview transcripts and they are classified using several keywords before the thematic analysis. Afterward, in System Dynamics modeling, these key elements and their structural interrelations are mapped and modeled to provide a holistic understanding of geothermal development complexity in Indonesia, incorporating both technical, economic, political, and social aspects. This System Dynamics model consists of balancing and reinforcing loops. The balancing and reinforcing loops were determined by the interrelationship between each element on System Dynamics, where the strengthening elements would result in reinforcing loops, while neutralizing elements would result in balancing loops (Sterman, 2001; Vitanov et al., 2007). This research is in line with Objective 6, which is identifying the dynamic elements of the chosen renewable energy, as well as Objective 7, which is proposing policy recommendations that favor the chosen renewable energy.

Following the previous research on objectives 6 and 7, the next research is focusing on developing a conceptual framework to analyze the geothermal energy sector as a part of the energy transition complexity that occurs through the developments on different system levels, namely, niche innovation levels, the regime, and the landscape (Geels, 2016). This research addresses Objective 4, which is analyzing the supply chain aspects for the chosen renewable energy in Objective 3, and objectives 5, which is analyzing the role ofthe chosen renewable energy in the context of the energy transition. The overall research process includes 2 stages. In Stage 1, qualitative information was analyzed using semi-structured interview method, with several stakeholders in geothermal energy in Indonesia, to identify the key elements that play roles in the journey of Indonesia's energy transition, especially those regarding the geothermal energy sector. Similar to the previous research on objective 6 and 7, the interviews were also conducted in Indonesian, audio recorded, transcribed, translated into English, and ultimately coded before thematic analysis. In Stage 2, these key elements and their structural interrelations are mapped and modeled to provide a holistic understanding of the complexity of energy transition in Indonesia, using the Multi-Level Perspective (MLP) approach.

The next few chapters consist of a series of research, which was made up of five research papers (one for each chapter), that have been published in Energies by MDPI, as a part of the requirement for Ph.D. by publication. The papers were all published in the same journal to maintain consistency and continuity of readership throughout the entire series of research. At the time of publication, Energies is a Q1 Scopus-index journal. Being an open-access journal, Energies offers additional benefits of rapid publication turn-around and allows easy-access to readers (especially in the developing world), hence increased potential citations.

Chapter 4: Paper 1 - A PESTLE Policy Mapping and Stakeholder Analysis of Indonesia’s Fossil Fuel Energy Industry

Paper accepted 9th May 2018 and published in Energies: Yudha, S.W., Tjahjono B., Kolios, A., (2018) A PESTLE Policy Mapping and Stakeholder Analysis of Indonesia’s Fossil Fuel Energy Industry, Energies, 11(5), 1272; doi.org/10.3390/en11051272

Abstract

Indonesia has a long-standing history of reliance on fossil fuels, which reflects the country’s vast reserves of crude oil, natural gas, coal, and other resources. Consequently, the potential of Indonesia’s fossil energy industry is both complex and multi-layered. This paper aims to carry out a policy mapping and stakeholder analysis of Indonesia’s fossil energy industry, adopting a PESTLE (Political, Economic, Social, Technology, Legal, and Environmental) approach, which allows identification of multidisciplinary stakeholders and underlying relationships across the sector. The outcomes from the analysis indicated the importance of strategically aligning the stakeholders’ policies to the needs of other relevant stakeholders. Furthermore, the central and regional governments need to work closely in order to better sense if there is a change in the policy, be receptive to anticipating the potential impacts, and to avoid policies being executed in an isolated manner.

Keywords: PESTLE; stakeholder analysis; fossil energy industry; Indonesia

4.1. Introduction

Indonesia has energy resources that if utilized appropriately, can ensure national energy security and independence. According to the report from the Directorate-General of New Renewable Energy and Energy Conservation of Indonesia, these reserves consist of 3.6 billion barrels of crude oil and 100.3 TSCF (trillion standard cubic feet) of natural gas, or between 0.2 and 1.5 percent of total global reserves, respectively. Taking into account the production level of oil at 288 million barrels, and the production of natural gas at 2.97 TSCF, these figures are approximately equivalent to 13 years of oil production and 34 years of gas production. In addition, Indonesia has an estimated 28 billion tons of coal reserves, or 3.1 percent of total global reserves (British Petroleum, 2016). Indonesia also has potential Coalbed Methane (CBM) reserves of approximately 300 to 450 TSCF, dispersed in 11 coal basins in various locations in Indonesia, such as Sumatera, Java, Kalimantan, and Sulawesi.

Indonesia’s domestic oil consumption has increased from 1.2 million barrels per day in 2003 to 1.6 million barrels per day in 2013 and is projected to increase by 5–6 percent per year until 2030, according to a McKinsey report in 2018. This is partly due to the rising electrification requirements, from 90 terawatt-hours (TWh) in 2003 to 190 TWh in 2013, although many of the electric power generators in Indonesia rely on coal. Nonetheless, with the current patterns of coal consumption and export, if no new reserves are discovered, it is estimated that there will be a deficit of coal in 2046, and thus, it is estimated that Indonesia will be a net importer of energy in 2029, based on Indonesia Energy Outlook. Up-to-date figures on the evolution of fossil fuels supply and demand can be found in Reference (Dutu, 2016).

There is a sharp disparity between the rate of consumption and the meager reserves of energy resources, generating ubiquitous energy crises, such as power blackouts in a number of regions, shortages of oil fuels in outlying regions, and a lack of gas reserves for the industry sector as inducers of regional economic growth (Mujiyanto and Tiess, 2013). This has the potential to be a serious threat to future national energy security unless long-term strategic planning is considered. The lack of more accessible, cheaper, and cleaner energy sources will impede the industrial growth and development of the manufacturing sector in Indonesia, preventing the country from achieving the same performance as its neighbors (Rock, 2012). To this end, further investigation into the utilization of both conventional as well as sustainable energy technologies appears to be pertinent for further development and the economic growth of Indonesia (Hasan *et al.,* 2012; Jaelani *et al.,* 2017; Winarno *et al.,* 2016).

In order to support rising domestic energy demands, Indonesia has formulated a National Energy Policy (Kebijakan Energi Nasional/KEN) as a guide for energy management in order to strengthen energy security and independence as a supporting mechanism for long-term development processes. The National Energy Policy declared through the Indonesian Government Regulation No. 79 of 2014, contains four aspects of primary policies for managing national energy including, among others, the utilization of domestic energy in order to fulfill national demand and support energy diversification and conservation, taking into account environmental ramification. This Regulation also mandates the fulfillment of optimal primary energy composition by 2025: crude oil composition at less than 25 percent, natural gas at a minimum of 30 percent, and coal at a minimum of 30 percent. The regulation also mandates that in 2050, the composition of crude oil be at less than 20 percent, natural gas at a minimum of 25 percent, and coal at a minimum of 24 percent.

Since signing (and later ratifying) the Paris Agreement at the 21st Conference of the Parties of the United States Framework Convention on Climate Change in 2015, Indonesia's national energy policies began to reflect its international commitments to climate action and mitigation. The prevailing instrument of commitment is the Nationally Determined Contribution (NDC), which elucidates a quantitatively objective national target for emissions reduction encompassing five major sectors: energy, waste, industrial processes and product use (IPPU), agriculture, and land use, land-use change and forestry (LULUCF). The core of Indonesia's NDC is a pledge to unconditionally reduce greenhouse gas emissions by 29% by 2030, or 41% with international assistance. All subsequent regulations and roadmaps on energy are expected to reflect Indonesia's NDC and pledge; an expectation that necessarily entails a synergic and multi-sectoral approach among all stakeholders.

In 2013, the International Energy Agency (IEA) alongside the Economic Research Institute for ASEAN and East Asia (ERIA) released a brief titled "Southeast Asia Energy Outlook: World Energy Outlook Special Report." Their findings include the fact that the ten members of ASEAN—along with China and India—are pulling the "center of gravity of the global energy system towards Asia." In ASEAN, Indonesia is listed as the dominant producer of energy resources. Many of the key questions faced by Indonesia's fossil energy are also mirrored by those in neighboring ASEAN countries. Issues of fossil fuel subsidy reform, investment in energy infrastructure, energy efficiency, and renewables development are sweeping across the board. Given the geographic and geopolitical similarities among ASEAN member states, a full-fledged stakeholder analysis of Indonesia's fossil fuel industry may assist further research in revealing similar intricacies in other Southeast Asian countries. Relevant literature on industrial developments in ASEAN countries can be found in (Fujita and Hamaguchi, 2016; Pappas, 2017; Bassino, 2018).

This paper aims to carry out a policy mapping and stakeholder analysis of Indonesia's fossil fuel energy industry through a PESTLE approach, with the ultimate goal of identifying various obstacles that potentially hinder the attainment of the above targets and utilizing Indonesia's dispersed fossil fuel energy resources. The stakeholders may include agencies, institutions, and parties that play important roles in fossil energy production at both upstream and downstream levels. This review mainly focuses on reviewing and presenting legislation and internal national communications as relevant critical literature is currently limited.

4.2. Research Approach

The approach adopted in the research follows the so-called PESTLE analysis, a framework or tool typically used in business and management to analyze the environment they are operating in or are planning to launch new operations in or monitor the macro-environmental (external) factors that have an impact on that environment. PESTLE analysis consists of the following individual components: political, economic, social, technological, legal, and environmental, hence PESTLE. It is expected that this framework will facilitate understanding of the dynamics of the problem and it could be used to provoke further research directions. The individual aspects of the analysis are briefly presented below and in Reference (Mytilinou *et al.*, 2017).

Political: These factors usually determine the extent to which a government may influence the economy or a certain industry sector, for instance, the enforcement of environmental penalties for polluting industries. Political factors may include tax policies, fiscal policy, trade tariffs, etc., which may significantly affect the business or economic environment.

Economic: These factors directly impact the economic performance of an organization, market, industry sector, or even a country, and have resonating long-term effects. For example, an increased inflation rate would affect the way organizations modify the pricing structure of their products, influencing the purchasing power of consumers, and eventually changing the level of demand and supply for that economy. Economic factors typically include inflation rate, interest rates, foreign exchange rates, economic growth patterns, etc.

Social: These factors examine the social environment of the industry sector, economy, or market that impacts other factors such as demographics, cultural trends, population analytics, etc. An example of this can be the social perception of certain technologies with associated impacts and incentives which could increase or diminish acceptability from the local public.

Technological: These factors are related to the technological innovation that may affect the operations of an organization, industry sector, or market, be they favorable or unfavorable. This includes automation, R&D, and technological awareness that exists in the organization or market.

Legal: These factors take into account both policies and laws that affect the industry/organization from these angles and then map out the strategies in light of these legislations. These include safety standards, labor laws, consumer protection laws, etc., that affect business performance due to maintaining certain policies or adhering to certain directives.

Environmental: These factors include all those that are influenced or are determined by the surrounding environment. Environmental factors are certainly critical for the energy sector. Environmental factors include climate, weather, geographical location, global changes in climate, environmental offsets, etc.

A similar approach has been indicatively applied in the analysis of industrial sectors of interest, such as the renewable (Mytilinou et al., 2017; Kolios *et al.,* 2013; Kolios *et al.,* 2016; Islam and Mamun, 2017) and conventional (Climent Barba, 2016) energy industries. PESTLE analysis has often been used to analyze various problems more holistically, for example in identifying economic issues and the challenges that arise, specifically concerning the impact of fossil fuels on the environment, or the formulation of legal frameworks for the fossil fuel industry. By using PESTLE analysis, aging policies that are ineffective or inefficient can be identified more comprehensively, whereas new strategic policies can be formulated to help the development of the fossil fuel industry.

4.3. PESTLE Analysis

This section will discuss the detailed PESTLE analysis of the fossil energy industry. Stakeholders are hereby referred to as individuals, groups, or institutions that have interests or concerns in the state of affairs within an organization or industry, and typically can affect or be affected by the organization's actions, objectives or policies.

4.3.1. Political

4.3.1.1. Policies Related to Coal Mining

Indonesia's policies have a significant effect on the development of the fossil fuel industry due to the dynamic nature of demand and supply (Sulistio *et al.,* 2017; Schaffartzik *et al.,* 2017; Tanoto *et al.,* 2015). An example of this was felt when the Indonesian House of Representatives and the government, represented by the Ministry of Energy and Mineral Resources, together agreed to and enacted Law No. 4 of 2009 on Mineral and Coal Mining, which mandated that obligations for value-adding activities should be done by spurring the development of domestic mineral smelters. The primary aim of this law is to add value to mineral outputs produced in Indonesia. For example, the bauxite commodity can yield 30 times added value when converted from raw materials into a final product; 19 times for nickel; 11 times for copper; and 12 times for lead (value chain optimization).

In the Appendix to the State Speech of the President of the Republic ofIndonesia during the 71st commemoration of the country's proclamation of independence, the President expounded on a policy course focused to fulfil domestic needs and increase the added value of mining products, as well as optimize the principles of mining conservation through various strategies. These strategies include perfecting Domestic Market Obligation (DMO) (DMO is an obligation for producers to sell a portion of their domestic production at a predetermined price (not the market price)) and Domestic non-DMO (D non-DMO) patterns, in which the government restricts the export of strategic mining products in order to ensure the sustainability of raw material supplies; forming an aligned consensus between the expansion of the industry for the processing of mining resources and the expansion of the manufacturing industry; and the geographical expansion of strategic mining product-based industries.In ensuring and supervising the implementation of national development plans, specifically in the energy and mineral resources sector, the President is assisted by the National Development Planning Agency.

In an attempt to attain energy security and independence, the Ministry of Energy and Mineral Resources, as the institution in charge of the sector, has requested coal producers to reserve a certain amount of their production for domestic consumption. In addition, the government uses export taxes imposed by the Directorate-General of Customs and Excise of the Ministry of Finance to reduce coal exports, (i.e., currently at 80 percent of the total coal production). This is implemented through the Letter of Decree of the Directorate-General of Mineral and Coal Number 1118/36/DJB/2014, which changes DMO policies for supply obligations in accordance with prevailing contracts; in the event of a shortage of domestic coal supplies, there will be an assignment of suppliers.

This has implications for coal production which in 2015 was 393 million tons, (i.e., less than the year before (2014) at 458 million tons). However, the reduction of national coal production is a result of a control attempt, so that domestic utilization could increase proportionately. According to the report from the Indonesian Mining Association, the allocation of domestic coal utilization in 2015 reached 20 percent, or approximately 79 million tons, with the following average DMO needs: 64 percent for PLN (National Electricity Company); 17 percent for Independent Power Producers (IPP); 2 percent for non-PLN and non-IPP power plants; 16 percent for cement, fertilizer, etc.; and 1 percent for the metallurgy industry. This allocation of domestic coal use was higher than in 2014, which only reached 17 percent or around 76 million tons.

The policy to increase DMO and necessitate domestic processing and refinery has induced conflicting opinions among investors. On the one hand, it gives domestic industries the chance to benefit from multiplier effects, on the other hand, business players feel burdened due to lower domestic prices compared to selling abroad.

In addition, several problems occur in the down-streaming of mining activities: firstly, there is still a limited mastery of processing and refinery technologies; and limited infrastructure in energy and transportation is also an obstacle (Dutu, 2016). Apart from that, the domestic downstream industry is still not sufficiently developed to be able to absorb semi-final and final mining products. The decline in mineral commodity prices causes the economy of refinery development projects to be unattractive and impeding financial support from investors or banks is also a hindering factor. There are also other problems, such as unlicensed mining, which reduces the overall quality of mining products, environmental degradation due to poor mining and processing practices, and soaring mining permit numbers due to the poorly regulated implementation of regional autonomy and decentralization.

4.3.1.2. Policies Related to Oil and Gas Production

In the oil and gas industry, the Ministry of Energy and Mineral Resources is the regulator for both the upstream and downstream sectors. In conducting its task as the regulator, in the upstream sector, the Directorate-General of Oil and Gas (Ditjen Migas, Jakarta, Indonesia) is assisted by the Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas, Jakarta, Indonesia); whereas in the downstream sector, Ditjen Migas is assisted by the Regulatory Body for Downstream Oil and Gas (BPH Migas, Jakarta, Indonesia), which is also tasked to determine the quotas for subsidized fuel for each region according to their needs. According to President Regulation No. 9 of 2013 on the Implementation of the Management of Downstream Oil and Gas Activities (Perpres SKK Migas), as well as Regulation of the Minister of Energy and Mineral Resources No. 9 of 2013 on the Organization and Working Procedure of the Special Task Force for Upstream Oil and Gas Business Activities, SKK Migas implements the conduct of management for upstream oil and gas activities. In undertaking its task, SKK Migas reports its results to the President through the Minister of Energy and Mineral Resources, as well as to the House of Representatives. In 2015, SKK Migas reported to the House of Representatives that crude oil production reached 788 thousand barrels per day, or 95 percent of the target agreed on by the government and Commission VII of the House of Representatives, amounting to 825 thousand barrels of oil per day (BOPD). Meanwhile, in 2015 natural gas production reached 1194 thousand barrels of oil equivalent per day (BOEPD), or 97 percent of the target of 1221 thousand BOEPD. In 2015, the allocation of domestic natural gas utilization reached 59 percent or approximately 705 thousand BOEPD. This figure is higher than the previous year, which only reached 56 percent or approximately 829 thousand BOEPD.

To achieve the lifting target agreed by Commission VII of the House of Representatives and the government in a budget meeting, Contractors of Oil and Gas

Cooperation Contracts (KKKS) face several obstacles: the global factor, namely a sharp decline in oil prices in early 2014 after being relatively stable at USD 100 per barrel for 3.5 years, triggered by oversupply and stagnation of the global economy, has induced postponement of investments. According to the Directorate-General of Oil and Gas of Indonesia, KKKS also faces geological problems, wherein there is a sharp natural decline rate of approximately 29 percent. KKKS is also hampered by several subsurface difficulties, such as operational difficulties, difficulties in land-clearing and permits, difficulties in procurement, low domestic absorption of gas purchases, and difficulties in managing working areas (Wilayah Kerja/WK), especially for working areas that are approaching the end of their contract periods.

With regard to the low domestic absorption of gas purchases, the government released Economic Policy Package Volume III targeting a reduction of natural gas prices for industries through a President Regulation on the determination of natural gas prices, in effect since 1 January 2016, which asserted that: the Minister of Energy determines the price of natural gas for the domestic market in the event that natural gas prices according to the existing economic conditions do not fulfill the economic requirements of gas-utilizing industries, and the price of gas is higher than USD 6/MMBTU, and the mechanism for price reduction is implemented through a reduction of non-tax state revenues from sales of natural gas. Lastly, the price reduction will also be implemented through the regulation of gas prices by the Directorate-General of Oil and Gas and BPH Migas at the downstream side, through the determination of a tariff for natural gas distribution which encompasses liquefaction, compression, transport through transmission and distribution pipes (the majority of which are owned by state-owned enterprises), the transport of liquefied natural gas and compressed natural gas, storage, regasification, and/or commerce and acceptable margins. This government policy has the potential to reduce gas prices by up to 30 percent, make the operational upstream more efficient, review the profit-sharing system in order to adapt to the fluctuation of global oil prices and reduce multiple prices due to the control of gas allocation by traders who do not necessarily have an infrastructure.

In addition, KKKS Contractors face obstacles when dealing with Provincial and Regency Governments, represented by regional Communication Forums for oil and gas producers regarding differences in oil and gas lifting calculations, which has consequences for the profit-sharing fund determined by the Ministry of Finance.

The analysis presented above concerns political stakeholders related to fossil energy; However, an enhanced network of relevant stakeholders has been formed for alternative fuels (Khatiwada and Silveira, 2017; Putrisari *et al.*, 2016; Silitonga *et al.*, 2011). Further discussion can be found in the literature on the need for a further energy policy strategy (Mujiyanto and Tiess, 2013).

4.3.2. Economic

4.3.2.1. Contribution of Fossil Fuels to Economy

The mining sector contains commodities that provide significant revenues to the state and economy. According to a report from Coordinating Ministry for Economic Affairs, from 2010 to 2015, the mining sector still dominated the economy with an average contribution of approximately 28 percent per year, followed by the agriculture sector with an average of 14.9 percent per year, and the manufacturing sector with an average of 13.2 percent per year. Overall, the contribution of the energy and mineral resources sector towards Indonesia's Gross Domestic Product (GDP) in 2015 was 1402 trillion rupiahs or 12.1 percent of Indonesia's total GDP (11,541 trillion rupiahs), according to the Ministry of Energy and Mineral Resources (MEMR) report.

Meanwhile, its contribution to the state budget can be seen in Indonesia's State Budget. In 2014, non-tax state revenues from the mineral and coal subsector reached Rp 35.5 trillion, whereas mineral and coal investment reached USD 7.4 billion. In 2015, non-tax state revenues from mineral and coal increased to Rp 55.2 trillion, whereas investment decreased to USD 5.2 billion. The investment decline was caused by a decline in mining commodity prices, as well as the diminishing global investment climate over the previous few years.

Law No. 4 of 2009 on Mineral and Coal Mining which mandates obligatory processing and refinery has spurred 67 development plans of processing and refinery facilities for various mineral types, with a total investment plan of USD 6.5 billion (MEMR report, 2016). Up to June 2016, investment had reached USD 3.8 billion. According to the Directorate-General of Mineral and Coal of Indonesia's MEMR, it is estimated that by the end of 2016, there were 27 finished refinery units, comprised of 8 nickel, 2 bauxite, 1 manganese, 11 zircon, 1 lead and zinc, and 4 kaolin and zeolite facilities.

On the other hand, the oil and gas sector has contributed Rp 78.6 trillion of total state revenues within the 2016 State Budget (Rp 1822.5 trillion). Over the past several years, non-tax state revenues from the oil and gas resources sector experienced a downward trend due to falling global oil prices. In the 2016 State Budget, global oil prices were assumed to be USD 50 per barrel; however, early 2016 witnessed lows of approximately USD 30 per barrel.

The government continuously attempted to increase state revenues from the oil and gas sector in 2017, through five strategies that have been prepared by the government in order to stimulate state revenues from oil and gas: first, the monitoring of on-stream field expansion projects in 2017 in order to achieve predetermined timeframes (there are currently six projects-ready); second, the attempt to increase oil and gas lifting; third, supporting the optimization of effective and efficient upstream oil and gas activities; fourth, the optimization of natural gas utilization for stakeholders; and fifth, the policy implementation of natural gas prices based on the policy package decreed in a Government Regulation in order to spur domestic industrial growth and recuperate the investment climate (MEMR report, 2016).

4.3.2.2. Impact of Global Crude Oil Prices

The investment climate for the national upstream oil and gas sector is influenced by global crude oil prices. This can be seen from 2010 to 2013 when the oil prices were around USD 100 per barrel, and the investment trend for the upstream oil and gas sector crept upwards to 71.8 percent or USD 18.9 billion. However, when oil prices fell in mid-2014, the investment value of the upstream oil and gas sector fell by 1 percent, becoming USD 18.7 billion and by 2015, it had fallen 20.8 percent, becoming USD 14.8 billion (MEMR report, 2018).

Meanwhile, in 2016, in which the Indonesian Crude Price (ICP) for the year's first quarter reached only USD 36.16 per barrel, or lower compared to last year's USD 54.85 per barrel, oil and gas investments fell to USD 5.65 billion. This figure is comprised of USD 5.51 billion for block exploitation, and USD 141 million for block exploration. Block exploration is then divided again into USD 107 million for exploration activities, and USD 34 million for administrative activities.

However, the fall in oil prices actually helped Indonesia's trade balance. The Ministry of Trade, as the regulator of Indonesian export and import, issued a press release in March 2015, stating that "the export total for the month of February 2015 reached USD 12.3 billion while imports reached USD 11.6 billion. Therefore, a USD 738.3 million was achieved". This surplus was caused by the fall of imported oil and gas by up to 18.7 percent (month to month), whereas oil and gas exports only fell by 8.8 percent (month to month), according to the Ministry of Finance report. In its attempt to supervise the export and import of oil and gas and to realize national energy management, transparency, and eradication, the Ministry of Trade released Regulation of the Minister of Trade Number 03/M-DAG/PER/1/2015 dated 5 January 2015. This regulates stringency and supervision in logging and documenting incoming and outgoing oil and gas, by necessitating registration for exporters and importers in order to obtain Listed Importer and Listed Exporter status, as well as to obtain recommendations from the Ministry of Energy and Mineral Resources, to be submitted to the Ministry of Trade in order to receive Letters of Export/Import Approval.

4.3.2.3. Cost Recovery and Resource Reserves

The upstream oil and gas sector is also acquainted with the term "cost recovery," which is a return of operational costs from exploration and exploitation activities in the upstream oil and gas mining sector that have been approved by SKK Migas after KKKS has submitted their annual Authorization for Expenditures (AFE) and Plan of Development. These SKK Migas-approved figures then need to receive the approval of the House of Representatives, namely from both Commission VII and the Budget Committee. For the 2016 Revised State Budget, the Budget Committee determined a cost recovery budget or return of operational costs for upstream oil and gas activities of USD 8 billion. This figure is 30 percent lower than that allocated in the original 2016

State Budget (USD 11.4 billion). The cost recovery budget cutback was part of an attempt to reduce a deficit in the state budget.

This reduction could impact the volume of oil and gas produced by contractors; with shrinking budgets, there will be a consequent reduction of exploration and exploitation activities in the upstream oil and gas sector, when in fact exploration is urgently needed in order to increase oil and gas reserves and production. This is even more so given the fact that Indonesia is currently experiencing a deficit in oil and gas production with regard to fulfilling national needs.

The lack of discovery of any new domestic oil and gas sources has caused oil and gas reserves to dwindle. Through the first quarter of 2016, oil reserves amount to only 7018 million stock tank barrels (MSTB). Gas reserves have also fallen. In the first quarter of 2015, gas reserves were recorded at 151 trillion standard cubic feet (TSCF). However, the first quarter of 2016 saw it fall to 148 TSCF.

Well-drilling explorations by KKKS also show an annual decline. The Ministry of Energy and Mineral Resources recorded that in 2011, the number of exploration well drillings amounted to 107 wells. This then fell to 106 wells in 2012 and 101 wells in 2013. This figure continued to decline to 83 wells in 2014, and a mere 52 wells in 2015. Up until April of 2016, drillings only amounted to 10 wells.

4.3.2.4. **Economic Policy Instruments**

As a result of the circumstance where state revenues from the oil and gas sector have continued to decline as a result of falling oil production and prices, the government undertook a bold step by completely abolishing oil fuel subsidies, specifically the "premium" grade of oil fuel, within the 2015 Revised State Budget, from a previous subsidy of Rp 276 trillion. Oil fuel subsidies were still allocated for kerosene; there is also a special fixed subsidy for diesel fuel. In the 2016 State Budget, energy subsidies amounted to Rp 102.1 trillion, which were comprised of Rp 63.7 trillion for kerosene and diesel fuel, 3 km liquefied petroleum gas (LPG) canisters, liquefied petroleum for vehicles (LGV), as well as Rp 38.4 trillion for electricity subsidies.

Several years earlier, the State Budget was heavily allocated for subsidizing the energy sector. In the 2014 State Budget, subsidies for oil fuels and electricity reached the highest figure ever recorded in State Budget history, namely Rp 350.3 trillion, which consisted of Rp 246.5 trillion for oil fuel subsidies and Rp 103.8 trillion for electricity subsidies. These subsidies were a heavy burden on the State Budget's position. Meanwhile, capital expenditure budgets were considered to be negligible, particularly for infrastructure, thus affecting investment levels in the real sectors.

This was caused by significant potential ramifications from changes in oil prices. For example, in the transportation sector, a 16 percent reduction in diesel fuel prices will cause a 5–10 percent fall in transportation costs, whereas a 16 percent increase in diesel fuel prices will cause a 20–30 percent increase in transportation costs. In the logistics and food sector, a 3.5 percent decrease in oil fuel prices will cause the price of basic commodities to decrease by 0.1 percent, whereas a 16 percent decrease in diesel fuel prices will cause a 1–2 percent decrease in logistical costs. However, an 8 percent increase in oil fuel prices will cause basic commodity prices to increase by 2 percent; an 8 percent decrease in oil fuel prices will cause a 0.04 percent deflation, whereas an 8 percent increase in oil fuel prices will cause a 2.8–3 percent inflation according to the Central Statistics Agency in 2016.

4.3.2.5. Investments in the Energy Supply Sector

As the central bank, Bank Indonesia is also a stakeholder within the oil and gas industry. In 2015, Bank Indonesia released a Regulation of Bank Indonesia (BI) Number 17/3/PBI/2015 on Obligations on the Use of Rupiah in Territories of the Unitary State of the Republic of Indonesia. However, BI made an exception for transactions of goods and services in upstream oil and gas activities. Working contracts between oil and gas companies and domestic vendors are still permitted to use foreign currency; however, payment must be done in rupiah. In this case, SKK Migas cooperated with three national state-owned banks to provide exchange rate transaction services for payment contracts between oil and gas companies and vendors.

In the electrification sector, the Directorate-General of Electricity and Energy Utilization recorded that in 2015, the national electrification ratio reached 87.5 percent; a 4 percent increase from 2014, which was at 84.1 percent. Furthermore, electricity consumption per capita increased by 843 kWh from that of 2014. Meanwhile, in 2015, increases in power plant capacity reached 2464 MW, higher than in 2014, which was 2,320 MW. The results of these developments were part of an infrastructure development acceleration program devised by the government. This acceleration program is aimed to increase competency, as well as fulfill rising electricity supply needs. This program is comprised of the construction of 7.4 GW of ongoing power plants and 35.5 GW of new power plants, as well as related transmission and distribution networks, targeted for completion between 2015 and 2019. An interesting case study on the costs of electricity investments for Indonesia can be found in Reference (Rohi *et al.*, 2015).

Throughout 2015, the electricity sector dominated investment plans that went to the Investment Coordinating Board (BKPM). BKPM recorded Rp 707.37 trillion of principle license applications in the electricity, gas, and water sectors from 1 January to 28 December 2015, or 37.51 percent of total incoming investment plans during that period (Rp 1886 trillion); this figure increased 45.29 percent from principle license applications in 2014, reaching Rp 1298.1 trillion (Nasrul, 2017). The high figure of investment plans in the electricity sector attests to enthusiasm among investors in embracing the government program to build 35,000 MW in the next five years. In the long run, investment in the electricity sector could support the expansion of investments in other sectors, through the availability of electricity resources and adequate infrastructure.

The 35,000 MW megaproject, to be supplied by coal, gas, and renewable energy sources, requires at least USD 73 billion of investment funds, not including budget requirements for land clearing, interest during construction as well as taxes. If consistently implemented, the 35,000 MW program could have multiple effects, such as being able to directly absorb a 650 thousand workforce, and indirectly a 3 million workforce. Domestic component levels could also rise by 40 percent out of total investments, or USD 29.2 million (Duta, 2017).

One attempt to spur investments in the electricity sector is to increase coordination between stakeholders such as related ministries and institutions, specifically the Ministry of Energy and Mineral Resources, and PT PLN (the State Electricity Company) as the electricity off-taker for the public. Licensing reforms have started to bear fruit. BKPM and other ministries have succeeded in cutting back permits in the electricity sector, from 49 permits requiring 923 days for administrative handling, to 25 permits in 256 days. In addition, the government also gives tax allowance facilities for investment in the electricity sector, with a guaranteed 28 days in processing requirements and time through the Central One-stop Integrated Service (PTSP Pusat) at BKPM. Apart from the Ministry of Energy and Mineral Resources, the Ministry of Agrarian Affairs and Spatial Planning has also interactively coordinated with BKPM on the Central One-stop Integrated Service, in order to mitigate obstacles to incoming investments in the real sectors. Some interesting work on business models for the development of energy investments in Indonesia can be found in (Jupesta *et al.,* 2017). It is important to state that for the evaluation of different investments, systematic life cycle costing models should be employed such as the one presented in (Ioannou *et al*., 2018).

4.3.3. Social

4.3.3.1. Impacts of Fossil Energy Extraction

Fossil energy extraction in Indonesia has had significant impacts on the Indonesian people, especially around areas of operation. For example, in 2015, South Kalimantan’s economic growth rate decreased from the previous year, from 4.85 percent to 3.84 percent. This growth rate is lower than the national growth rate, which reached 4.84 percent in 2015 (Silitonga *et al.,* 2011). South Kalimantan’s deteriorating economic growth was caused, among others, by the impacts of stagnating global economic growth, especially in China, as well as the decline of several commodities in the international market, including mineral and coal prices. These also directly caused the growth rate of the mining sector to register negative figures.

In addition, fossil energy extraction can potentially instigate problems, including large-scale deforestation (Sheikh and Gorte, 2008), air pollution, concession conflicts with local and indigenous communities, as well as adverse health impacts from coal dust. In addition, many cases of conflict occur in regions of small-scale miners, such as in Bangka-Belitung, Kalimantan, and Maluku Utara; these cases are usually related to the ambivalent understanding of small-scale mining itself. Consequently, all forms of mining activities are undertaken by communities; any region with active, whether simple or heavy, machinery can claim to be the location of small-scale mining enterprises.

4.3.3.2. Initiatives for Further Social Development

In the upstream oil and gas industry, based on Law No. 22 of 2001 on oil and gas, the implementation of oil and gas business activities is aimed to, among others, create job opportunities, increase levels of public welfare and wealth that are both fair and equitable, as well as continue to safeguard biodiversity. This can be seen in data from SKK Migas, which shows that absorption of the Indonesian workforce has continued to increase concurrently with an increase in the number of Contractors of Oil and Gas Cooperation Contracts (KKKS) who conduct explorations in new and existing oil and gas working areas. Up until the end of 2014, the upstream oil and gas sector absorbed 32,292 members of the Indonesian workforce, compared to 1165 foreign workers (3.6 percent). This means that percentage-wise, the number of national workers in the upstream oil and gas industry has reached 96.4 percent [60]. Regarding the utilization of foreign workers, KKKS needs to consult and comply with prevailing regulations concerning labor standards from the Ministry of Labor and SKK Migas.

4.3.4. Technological

In order to optimally harvest and convert energy from fossil sources, employing state-of-the-art technologies and engineering practices stands as a necessary condition. This section presents in a generic way the relevant methods, namely clean coal, and enhanced oil recovery.

4.3.4.1. Clean Coal Technologies

Considering the environmental impacts of gas emissions from coal usage, as well as the unavoidable utilization of coal to fulfill rising energy needs, the implementation of technology to reduce pollutants from coal usage needs to be considered. This technology is usually referred to as Clean Coal Technologies (CCT). A comprehensive presentation of CCT can be found in Reference (Clemente, 2013). This technology can be classified based on the level of energy production processes in its implementation, which encompasses technology for pre-combustion, combustion, post-combustion, and coal conversion. In pre-combustion technologies, coal needs to first be cleaned; the primary aim of this cleaning process, which occurs before combustion, is to reduce or remove waste, especially sulfur contents which are organically unbounded to coal. Coal cleaning can also improve the amount of heat recovered, thus increasing heat generation efficiency. Traditionally, pre-combustion coal cleaning technologies consist of two methods, namely physical cleaning and chemical cleaning. Meanwhile, new methods for coal cleaning encompass biological cleaning, which is developed concurrently with advances in microbe and enzyme techniques in order to release sulphur and ash from coal (Speight, 1994).

Combustion technologies encompass techniques that also prevent pollutant emissions during the combustion process. Coal cleaning during combustion removes emissions from coal when the coal is being combusted. This can be achieved through the control of combustion parameters such as fuel, air or oxygen, and temperature. Several techniques are used to remove SO2 emissions or to limit NOx during combustion, which concurrently can improve heat efficiency. There are several technologies available, such as Furnace Sorbent Injection (FSI) and Pressurized Fluidized Bed Combustion (PFBC). Meanwhile, for post-combustion technologies, waste gas released from the boiler is given treatment to reduce pollutant contents. All newly implemented post-combustion technologies, such as gas cleaning to reduce SO2 and NOx emissions, as well as dust particles (in several cases) simultaneously from smokestacks, are still being developed. These CCT encompass, among others, Flue-gas Desulfurization (FGD), Regenerable Flue-gas Desulfurization Systems, and Selective Catalytic Reduction (SCR). Lastly, coal conversion is the conversion of coal into a gas or liquid form that can be cleaned and used as fuel. Other CCTs are coal conversion technologies that first convert coal from its solid form into other forms such as gas or liquid. These technologies are still in the trial and development phase. Technologies for developing the coal conversion process encompass, among others, Integrated Gasification Combined Cycle (IGCC) and Integrated Gasification Fuel Cell (IGFC) (Suarna, 2011). An interesting case study of coal substitution for a specific industry in Indonesia can be found in Reference (Ummatin and Arifianti, 2017)

Concerning the global implementation of technologies for coal liquefaction, South Africa is ranked number one—much of this can be observed in R&D for indirect coal liquefaction; currently, South Africa supplies approximately a third of its domestic liquid fuel needs from coal (Coal to Liquid, CTL). China is also experiencing growth in coal liquefaction as a technique to utilize overabundant coal reserves and reduce its dependency on imported oil (World Coal Institute report, 2017).

4.3.4.2. Enhanced Oil Recover

In the oil and gas industry, Indonesia's oil production has taken place for almost a century and a quarter since the first drilling discovery at the Number 1 Telaga Tunggal well in 1885, at the concession area in Telaga Said, Tanjung Pura, Sumatera Utara. Indonesia experienced peak production in 1977 and 1995. Peak production in 1977 was the highest level of production from primary recovery, whereas peak production in 1995 was the result of the implementation of the EOR (enhanced oil recovery) method through steam injection at the Duri field by a KKKS, namely Chevron. This project's field-scale development started in 1985. From 1995 to 2010, Indonesia's oil production continued to decline. Starting from 2007, the rate of decline managed to be mitigated due to contributions from new fields, namely Banyu Urip by Exxon and the state-owned Pertamina. This is in accordance with basic principles introduced by King Hubbert in the 1950s, which stated that production will gradually continue to rise until the highest attainable peak, at which point production will decline until resources run out (Bentley, 2002). This indicates that increasing Indonesia's oil production, or attaining the third Hubbert cycle, is only possible with the massive implementation of EOR technology, or with adequately large discoveries of new oilfields.

The EOR method is classified into four main categories; the first is chemical flooding. Chemical fluids which are most often used are polymer, surfactants, and alkaline, or a mixture of two or three of these chemicals. In polymer injection, a typical solution of hydrolyzed polyacrylamide with water formation in concentrations of several hundred to thousand ppm of polymer is injected to push oil into production wells. The second method is miscible gas injection; miscible gas injection is a process of oil displacement by fluids that will mix with oil to form a special condition at the reservoir. The third method is the thermal method. The process of oil recovery through the thermal method is primarily applied in reservoirs that contain heavy oil with high viscosity. Heat can be supplied from outside the reservoirs through steam injection or hot water, or can be generated inside the reservoir itself through combustion. Well-recognized external thermal injections are hot water injection or steam injection; these two injections primarily serve to reduce oil viscosity in order to improve the oil's mobility (Prats, 1986). The last method used is microbial enhanced oil recovery (MEOR); this method is an EOR technology that does not require large investments. Unfortunately, the credibility of this technology has not been fully acknowledged by the oil industry due to technical and economic reasons (Maudgalya, 2007).

4.3.4.3. **Other Technologies**

Energy storage technology is another sector of oil and gas technology that is sorely needed to ensure energy security. In Indonesia, this is inevitably tied to its energy policy: Indonesia does not currently have a strategic petroleum reserve and only has enough fuel to last 21 days. A strategic petroleum reserve would potentially boost Indonesia's fuel reserves to more than 40 days. Within the current stakeholder framework, a strategic petroleum reserve would possibly involve Pertamina, the state oil company. Pertamina would then have to construct and utilize storage tanks with the specific purpose of stockpiling its petroleum reserve. Further comparative studies must be undertaken in this field in order to acquire both technical and political know-how from countries that have already succeeded in implementing strategic petroleum reserves, such as the United States with its 713.5 million barrel-capacity strategic petroleum reserve in underground salt caverns. Further up-to-date literature on industrial applications of energy storage can be found in References (Aneke and Wang, 2016; Strasser *et al*, 2015; Zafirakis *et al.*, 2014).

Although this section has focused on relatively conventional technologies, it should be noted that increased demand and energy security will be achieved from a mix of technologies taking advantage of the great potential of Indonesia. This includes advanced technological developments in the biofuels sector (Jupesta, 2010; Jupesta, 2012) as well as the utilization of geothermal energy (Nasution, 2012) potential, where Indonesia is among the countries with the highest recovery potential globally.

4.3.5. Legal

The 1945 Constitution of the Republic of Indonesia, Article 33, paragraphs (2) and (3), asserts that sectors of production that are important for the country and affect the life of the people shall be under the powers of the state and shall be used to the greatest benefit of the people. Oil and gas, being strategic non-renewable natural resources that are vital commodities affecting the life of the people, must therefore be controlled and managed optimally by the state, in order to provide the largest benefits for the well-being and welfare of the people.

4.3.5.1. Legislation on Mineral and Coal Mining

The mandate of the Mineral and Coal Mining Law, which includes processing and refinery, is also regulated in the Industry Law, wherein the construction of every smelter must possess an Industrial Business License; this is compliant with the mandate contained in Article 101, paragraph (1) of the Industry Law, which states: “Every industrial business is required to possess an Industrial Business License”. These businesses encompass small, medium, and large industries. To date, the requirement for processing and refinery industries to possess a Mining Business License Exclusivelyfor Processing and/or Refinery has bewildered investors in the processing and refineryof minerals and coal, due to overlapping authorizations between the Ministry of Energyand Mineral Resources and the Ministry of Industry. Therefore, there needs to be a One-stop Integrated Service (PTSP) to elucidate and simplify this licensing process.

With regard to share divestment, Article 3, letter (d) of the Law on Capital Investment states that the implementation of capital investment is based on the principles of equal treatment and does not discriminate based on national origin, which is strengthened further in Article 6 paragraph 1 of the aforementioned law, which states that the government provides equal treatment to all investors. The matter of sovereignty and independence certainly has a strong influence in relation to equal treatment between domestic and foreign investors; the potency of foreign capital clearly affects competition for the control of businesses. On the other hand, this term gives legal assurance and guarantees for foreign investors to freely participate in capital investments, which are realized in various businesses, including oil and gas. However, in Article 7, paragraphs 1 and 2, the Law on Capital Investment is still open to the possibility of returning foreign shares through nationalization or acquisition of the ownership rights of investors. This is related to Article 79 letter (y) of the Law on Mineral and Coal Mining, which necessitates Special Production Business Licenses to accommodate divestment. Article 112 of the Law on Mineral and Coal Mining furthermore reasserts that after five years of production, businesses that possess Production Business Licenses and Special Production Business Licenses and whose shares are foreign-owned must divest their shares to the central government, regional government, state-owned enterprises, regionally-owned enterprises or national private businesses.

The policing of mining activities continues to be undertaken and since 2014 the Corruption Eradication Commission has cooperated with the Ministry of Energy and Mineral Resources in coordinating and supervising the management of mineral and coal mining. Based on coordination and supervision activities, up to May 2016, there have been 10,378 Mining Business Permits issued in the entirety of Indonesia (6790 mineral mining permits and 3588 coal mining permits). From this figure, 6790 Mining Business Permits have Clean and Clear status (61.25 percent of total Mining Business Permits), whereas the rest are still problematic with regard to overlapping areas and administrative issues. This attempt has provided a breakthrough for state revenues. From the first quarter of 2014 to October 2014 in the Mineral and Coal Coordinating and Supervision action, there has been an increase in non-tax state revenues by Rp 7 trillion, and as many as 1254 Mining Business Permits have been revoked in 22 provinces (Abdul, 2017).

4.3.5.2. Legislation on Oil & Gas Production

Given their status as natural resources that can be used for the greatest benefit of the people, the management of oil and gas also complies with the system of the organization of the national economy, which is conducted on the basis of economic democracy upholding the principles of togetherness, efficiency with justice, continuity, environmental perspective, self-sufficiency, and keeping a balance in the progress and unity of the national economy, as elucidated in Article 33, paragraph (4) of the 1945 Constitution of the Republic of Indonesia.

The Law on Oil and Gas has incited legal matters in its implementation. This law has been through three assessments at the Constitutional Court. The Constitutional Court's three decrees on this law represent two important issues in the 1945 Constitution; the first concerns the system of implementation or management of oil and gas, whereas the second concerns institutions that manage oil and gas as the implementation of the concept of state control. The Decision of the Constitutional Court No. 002/PUU-I/2003 dated 21 December 2004 deals with the system of management for oil and gas, which, according to the Court, conflicts with the 1945 Constitution; there is also the Decision of the Constitutional Court No. 36/PUU-X/2012 [81] concerning institutions for the management of oil and gas.

The Decision of the Constitutional Court No. 002/PUU-I/2003 overrules Article 2 paragraph (3), Article 22 paragraph (1), and Article 28 paragraphs (2) and (3) of the Law on Oil and Gas [82], due to their conflicting with Article 33 paragraphs (2) and (3) of the 1945 Constitution; thus, the aforementioned overruled articles no longer have binding legal force. The Decision of the Constitutional Court No. 36/PUU-X/2012 has also overruled several articles and/or paragraphs within the Law on Oil and Gas. The Constitutional Court is influential in the disbandment of the state upstream oil and gas regulator (BP Migas). Based on this Decision, the Law on Oil and Gas requires amendments, especially concerning overruled articles as well as related articles that have implications for changes to the overruled articles.

Several terms within the articles were overruled by the Constitutional Court in the Law on Oil and Gas placing the state (government) in a weak position. The standing of the state upstream oil and gas regulator (BP Minyak dan Gas Bumi), as regulated in the Law on Oil and Gas, positions the government—in this case, BP Minyak dan Gas Bumi—as equal to upstream oil and gas businesses. This has given rise to legal relations between the government and businesses (Government to Business). It is this practice that the Constitutional Court viewed as demeaning the government's status.

The Law on Oil and Gas is perceived to have contributed to the mismanagement of Indonesia's natural resources, which has made the oil and gas industry fail to be the backbone of national energy security. This is marked by, among others, misdirected fiscal regulations, the establishment of a new and complicated chain of bureaucracy, inefficient operational costs (cost recovery) and corruption, the decline of nationalist self-esteem in oil contracts, as well as oil and gas policies that lack road maps. This, among others, has caused a decrease in oil and gas lifting, especially since 2004.

Some of the aforementioned problems call for the urgent need to revise the Law on Oil and Gas. One issue that is discussed in the revision of this Law is the form of business contracts for oil and gas. In oil and gas management from around the world, there are four types of business contracts that are typically used: Concession Contracts, Production Sharing Contracts, Service Contracts, and Joint Operating Agreements. These business contracts are formulated to fulfill the interests of two parties, namely the State as the proprietor of energy sources, as well as contractors.

4.3.6. Environmental

In an attempt to support sustainable national development, one of the aims of oil and gas resource management is to ensure the utilization of oil and gas mining sustainably from an environmental, social, and economic point of view (Siahaan *et al.*, 2016). In conducting environmentally sound oil and gas management, mining businesses must observe environmental sustainability. Literature presenting the current situation and supporting the formation of future strategies for Indonesia and neighboring countries has started to form a good body of knowledge as shown in Never and Betz (2014), Pao *et al.* (2014), and Van Ruijven *et al.* (2012).

***4.3.6.1.* Permits for Planning and Operation**

Before commencing any mining business or activity, Mining Business Permit and Special Mining Business Permit applicants must conduct a study on the large and important ramifications of a business or mining activity, which is then proven through an Environmental Impact Assessment document. In operating a business or mining activity, Mining Business Permit and Special Mining Business Permit holders must undertake reclamation and post-mining activities, which are conducted throughout the entire mining business cycle, in order to organize, restore, and rehabilitate the quality of the environment and the ecosystem so that these can continue to function. After a portion or the entirety of the mining business is carried out, holders of Mining Business Permits or Special Mining Business Permits must conduct post-mining activities which are planned, systematic and continuous, in order to restore ecological functions and social functions according to local conditions throughout the entire mining area.

In reality, mining permits are given without considering Strategic Environmental Assessments. This has implications for environmental degradation, which causes the loss of livelihood for communities that depend on the land (agriculture, fish farming) (Hooijer *et al.*, 2010). Environmental Impact Assessments are often copied from other Environmental Impact Assessment documents which do not depict accurate conditions on the ground. The publishing of these documents involves only specific people to legitimize them, giving rise to a purely ceremonial impression. Many communities around mines are unaware of the activities or ramifications of existing mining businesses. These problems occur due to a lack of supervision from the Regional Government regarding the publishing of Environmental Impact Assessments. There are few instances of attempts to ensure repercussions for companies that violate the conditions of these environmental licenses.

To date, the Environmental Impact Assessments have not been continuously monitored and evaluated. To strengthen Environmental Impact Assessments, there should be continuous monitoring and evaluation conducted in the form ofenvironmental and social audits by mine inspectors, so that Environmental Impact Assessments are not merely administrative documents that are unassessed and without continuous supervision. In the Appendix to the State Speech of the President of the Republic of Indonesia during the 71st commemoration of the country's proclamation of independence, the President urged an increase in strict supervision, especially concerning reclamation and post-mining activities, through the assignment of mine inspectors to monitor mining under Law No. 23 of 2013 on Regional Government, wherein authorization for licensing was shifted from the regency government to the provincial government as the representative of the central government.

***4.3.6.2.* Impact on Environmental Resources**

Apart from problems with Environmental Impact Assessments, there is also contamination and environmental degradation, especially in open-access land, i.e., land that is openly accessible for other parties to exploit illegally, thus having the potential to cause contamination and environmental degradation. Open access is due to inadequate supervision or even a lack of concern from various parties. One form of utilization of open-access land is for unlicensed mining. There are thousands of unlicensed mining locations which involve approximately 2 million miners.

In Law No. 32 of 2009 on Environmental Protection and Management, Article 112 regulates that every authorized official who inadvertently fails to conduct supervision on the compliance of accountable business actors, and/or on environmental activities and licensing, which then causes environmental contamination and/or degradation that causes loss of life, can be threatened with custody or a fine. In several regions, unlicensed mining has caused environmental contamination and degradation, social conflict, and even fatalities.

In the upstream oil and gas industry, there are several forms of pollution; the first is air pollution, for example, hydrocarbon gas which occurs in oil and gas exploitation activities. Hydrocarbon gas consists of methane (CH4), ethane (C2H6), propane (C3H8), isobutane (i-C4H10), butane (C4H10), and pentane (C5H12). Aromatic hydrocarbons, including benzene, toluene, and xylene are generally found in crude oil. These gases generally originate in oil and gas wells from oil and gas exploitation activities, thus designating them as natural gases. These hydrocarbon gases have a carcinogenic nature, which means that they can induce cancer in humans. In addition, there is also hydrogen sulfide gas (H2S) which is an associated gas that releases together with hydrocarbon gases from oil and gas wells, which emerges due to oil and gas exploitation activities. Hydrogen sulfide (H2S) is a colorless gas that is heavier than air, extremely toxic, corrosive, and pungent. Another example of gas is carbon dioxide (CO2), an inert and associated gas that releases together with natural gases, that emerges due to oil and gas exploitation activities, also as an inert gas from geothermal activities. In addition, CO2 is a pollutant from emissions produced from fuel combustion, both industrial- and transportation-related. It is a colorless and odorless gas that can reduce the heating value of natural gases. If combined with the presence of water, it will form a corrosive molecule. Also, CO_2 is the primary contributor to global warming. A review of possible scenarios for CO_2 reduction in Indonesia can be found in Suharta *et al.* (2017) while a review of policy and regulations has been performed in Chaniago (2017).

Apart from air pollution, industrial activities have the potential to pollute water. This can occur from drilling waste, such as mud residues that are the result of oil and gas exploration. Drilling waste also has the potential to affect the quality of surface water near exploration areas. Water from mines or oil wells that are still mixed with crude oil and gas that is carried to the surface from strata that contain hydrocarbons throughout the extraction of oil and gas have contained within them formation water injected water and chemicals that are added for drilling or the separation of oil and water.

4.3.6.3. **Governance and National Targets**

Article 40 of the Law on Environmental Protection and Management states that permits are required by businesses carrying out activities that potentially impact the environment. In the event that an environmental permit is revoked, business and/or activity permits are also revoked. If a business and/or activity changes, those in charge of the business and/or activity must renew their environmental permits.

In addition, there is the issue of government supervision over holders of Mining Business Permits. The government is not only authorized to release permits but also to supervise previously released ones. Government supervision encompasses, for example, pressuring those in charge of businesses and/or activities to conduct environmental audits in order to increase environmental performance, as regulated in Article 48 of the Law on Environmental Protection and Management.

The central and regional governments are obliged to compile Strategic Environmental Assessments to ensure that the principles of sustainable development are fundamental and integrated into the development of a region and/or policy, plan, and/or program. For this reason, the central and regional governments must integrate Strategic Environmental Assessments into the formulation or evaluation of a regional spatial plan along with detailed plans, long-term development plans, and mid-term development plans for the national, provincial, and regency/municipality levels, as well as for policies, plans, and/or programs that can potentially cause environmental impacts and/or risks (Article 15 of the Law on Environmental Protection and Management).

In its connection to air pollution, Indonesia’s development is aimed toward a low-carbon future. Currently, Indonesia’s greenhouse gas emissions are estimated to be 1800 $MtCO_2e$, 400 $MtCO_2e$ higher than required by 2020 (SNC), with the following composition: 63 percent is derived from land-use change in peatlands and forest and land fires, whereas 19 percent is derived from the use of oil fuels. What needs to be noted is that in 2000, the energy sector contributed 30 percent of total greenhouse gases, rising to 35 percent in 2012, according to Indonesia’s first NDC that was submitted to the UNFCCC.

Responding to this, the President has decreed two presidential regulations, namely President Regulation No. 61 of 2011 and President Regulation No. 71 of 2011, and also determined a national target for greenhouse gas reductions at 26 percent (unconditional) and 41 percent (conditional) by 2020 as opposed to Business As Usual (BAU). The same was stated by the Minister of Environment and Forestry at COP-21, which became the Intended Nationally Determined Contribution (INDC), and is in the process of becoming the Nationally Determined Contributions (NDC).

4.4. Discussion

Southeast Asia, specifically the Association of Southeast Asian Nations (ASEAN) has put its mark on the map in regard to global energy supply and consumption. In the past 15 years, the ten member countries of ASEAN have seen their energy demand grow by up to 15%; the International Energy Agency forecast in "Southeast Asia Energy Outlook 2017" that Southeast Asia's energy demand will rise by two-thirds in the period to 2040. The report also highlighted that, collectively, the ten member states of ASEAN are the world's seventh-largest economy and the fifth-largest destination for foreign investment in 2016. ASEAN's energy demand has increased by 70% since 2000, and the region currently contributes 5% of the total global demand. Despite the various geographic and economic differences, ASEAN countries as a whole are united in the fact that they face a common challenge: secure, affordable, and sustainable energy.

The history of ASEAN's economic cooperation in the field of energy can be traced to 1997 when ASEAN countries adopted a vision for energy cooperation called ASEAN Vision 2020. Among others, the vision highlighted the need for improved energy cooperation through integrated energy infrastructure projects such as electric grid interconnections and transnational natural gas pipelines. In 1999, ASEAN then formulated an ASEAN Plan of Action for Energy Cooperation (APAEC) 1999–2004, which has since been updated with versions for 2004–2009 and 2010–2015. APAEC's primary objectives encompass energy security, accessibility, and sustainability for the ASEAN region. The latest version of APAEC (2010–2015) lists seven main energy cooperation program areas, namely: (1) The ASEAN Power Grid (APG); (2) The Trans-ASEAN Gas Pipeline (TAGP); (3) Coal and Clean Coal Technology; (4) Energy Efficiency and Conservation (EE&C); (5) Renewable Energy; (6) Regional Energy Policy and Planning; and (7) Civilian Nuclear Energy.

As an ASEAN member state, Indonesia plays a vital role in realizing regional energy security aspirations. For example, demand for natural gas in the ASEAN region is expected to increase by 60% by 2040 due to rising consumption in power generation and industry. Consequently, Indonesia's progress in securing the East Natuna natural gas field is pivotal for the region if, in accordance with APAEC provisions, a more integrated natural gas infrastructure is expected to be developed. Further discussion on the context of energy supply security can be found in (Shadman *et al.,* 2016; Sovacool *et al.,* 2011; Chalvatzis and Rubel, 2015).

The stakeholders identified through the PESTLE analysis and who are involved in the fossil fuel industry are listed in Table 4. Knowledge of relevant stakeholders within the oil and gas industry can be used as a reference when formulating new policies because it can enhance the understanding of the implications of new policies for the stakeholders involved. For example, if the government, through the Ministry of Energy and Mineral Resources, decides to postpone down-streaming, this can cause investors who had previously planned to invest their capital in the construction of smelters to postpone their decisions. This is also an indication of the importance of stability and government consistency in policy implementation so that investors can adjust their IRR with initial plans.

This can be achieved by creating a balance between the needs of regulators that represent the interests of the state, the mandate of the constitution as well as prevailing laws and regulations, and the needs of investors that can also open up new jobs and bring in technology that is mutually beneficial, given the need for investment in the energy sector, both in the construction of infrastructure and to increase the production of oil in order to attain energy security.

Stakeholders' policies can become problematic if these policies do not comply. An example is the authorization of the Ministry of Energy and Mineral Resources by the Ministry of Environment and Forestry concerning matters of land usage permits; this is because companies that receive Licenses to Operate from the Ministry of Energy and Mineral Resources are not necessarily ensured to obtain permits from the Ministry of Environment and Forestry.

Furthermore, there needs to be a paradigm shift from previously-held views that the management of fossil energy is in order to produce profit, to be an 'engine' of economic growth. The regulations will also need to be revised to embrace the transition from a fossil fuel economy to a non-fossil fuel economy, owing to Indonesia's dwindling fossil energy resources.

Utilizing the PESTLE-based topological overview as it is summarized in Table 4, it is possible to identify and map the involvement of stakeholders involved in the fossil energy industry in Indonesia. This map highlights all the relevant stakeholders and their influence in the six PESTLE-based sectors that constitute the fossil energy industry. In addition, to identify the extent of the stakeholder roles within the PESTLE framework, the table also serves to depict the importance of strategically aligning the stakeholders' policies to the needs of other relevant stakeholders.

Table 4. Stakeholders of the fossil energy industry in Indonesia.

Stakeholders	Political	Economic	Social	Technology	Environment	Legal
Commission VII of the House of Representatives of the Republic of Indonesia	√				√	√
Budget Committee of the House of Representatives of the Republic of Indonesia		√				
President of the Republic of Indonesia	√				√	
Ministry of Energy and Mineral Resource	√	√				
Ministry of Labor			√			

Ministry of Environment and Forestry					√	
Ministry of Agrarian Affairs and Spatial Planning		√				
Ministry of Transportation			√			
Ministry of Maritime Affairs and Fisheries					√	
Ministry of Finance		√				
Ministry of Trade		√		√		
Ministry of Industry		√				√
National Development Planning Agency		√				
Corruption Eradication Commission						√
Finance and Development Supervisory Agency						√
Supreme Audit Agency						√
Bank Indonesia (Central Bank)	√	√				
Constitutional Court						√
Investment Coordinating Board		√				
Special Task Force for Upstream Oil and Gas Business Activities	√		√			
Directorate-General of Electricity and Energy Utilization		√				
Directorate-General of Mineral and Coal	√					
Directorate-General of Oil and Gas	√					
Regulatory Body for Downstream Oil and Gas	√					
Directorate-General of Customs and Excise of the Ministry of Finance	√					
State-owned Enterprises	√	√				
Regionally-owned Enterprises	√	√				
National Banks		√				
Regency Government				√	√	
Provincial Government				√	√	
PLN (State Electricity Company)		√				
Contractors of Oil and Gas Cooperation Contracts	√		√	√	√	
Investors	√					
NGOs						√
Communication Forum of Oil and Gas Producing Regions		√				
Natural Gas Traders	√					
Public		√				

While it is not institutionally limited in the scope of its sampling, the table represents the various government ministries and bodies, investors, NGOs, private contractors, business actors, traders, as well as the entire public. Thus, this allows intervention into the question of who might be affected, either positively or negatively, by such policies relevant to the fossil fuel energy industry. It is, however, perhaps too early to tell the limits of its practical application in Indonesia; any integration or intervention using a PESTLE approach would entail having to first identify suitable enablers for policy formulation, particularly within the turbulent seas of market data and political forecasting.

It should be noted that a limitation of the application of this method in this paper, lies in the fact that the review has been based mainly on a review of regulations, academic papers, and reports for Indonesia. At the next level, a series of structured interviews across the six macroeconomic sectors could provide further insights into the actual application and applicability of the various policies that are in place.

Aside from the necessary fundamental and crucial purpose of policymaking, further contextually-specific analyses can serve the interests of the general public in ways that go beyond the formalistic legal framework. NGOs and other elements of the society concerned with the social or environmental issues associated with the fossil energy industry can also be formulated through a holistic plan of action. Lastly, private investors and business actors can also discover the extent of the web of stakeholders in order to better endorse the business process.

4.5. Conclusions

PESTLE analysis has been carried out in this paper in order to identify relevant stakeholders and their complex relationships within the fossil energy development sector and to map relevant existing policies. It also provides a clear picture of the environment and circumstances the stakeholders are operating in, enabling the monitoring of various factors that may have an impact. The identification of relevant stakeholders within the fossil energy sector is thus useful to support policymakers in formulating new energy policies and helping recognize the implications of these new policies to the stakeholders involved.

PESTLE allows a more holistic analysis of various challenges faced by the fossil energy industry to be carried out. The multi-faceted approach can potentially reveal the policies that are ineffective and uphold the development of new strategic public policies. From the political, economic, social, technological, legal, and environmental aspects of the analysis, it is evident that the development of public policyon fossil energy in Indonesia requires close collaboration between the central and regional governments. This is crucial as any irregularities and discrepancies as a consequence of a change in the policy would need to be quickly detected. Thegovernment also needs to be more receptive to anticipating the potential impacts of thepolicies in their entirety so as to prevent the policy from being executed in a stand-alonemanner.

Chapter 5: Paper 2 - Stakeholder Mapping and Analysis of the Renewable Energy Industry in Indonesia

Paper accepted 2nd February 2019 and published in Energies: Yudha, S.W., Tjahjono B., (2019) Stakeholder Mapping and Analysis of the Renewable Energy Industry in Indonesia, Energies 2019, 12, 602; doi:10.3390/en12040602

Abstract

The development of renewable energy in Indonesia is still in a relatively fledgling state, yet it is forecast to increase. The Government of Indonesia has formulated and implemented several strategic programs, compiled under several binding frameworks, namely the National Energy Policy and the General Plan for National Energy. The government is committed internationally to reduce its greenhouse gas emissions as part of its Nationally Determined Contributions. However, unearthing the dynamics of renewable and sustainable energy in Indonesia requires a detailed stakeholder analysis of all relevant and major actors. This paper aims to provide a stakeholder analysis of actors in the renewable and sustainable energy sector in Indonesia as a whole, using a Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis methodology. The results have indicated that existing policies are not yet perfect, given that the renewable energy industry is still quite minimal, especially in the current conditions of falling oil prices. In the future, it is hoped that the government can formulate a breakthrough policy to improve existing policies in the renewable energy sector, such as by giving ease to investors in the renewable energy sector, including the effective and efficient supply chain management of renewable energy.

Keywords: PESTLE; stakeholder analysis; renewable energy; sustainability; policy; Indonesia; supply chain management

5.1. Introduction

In the renewable energy sector, the Association of Southeast Asian Nations (ASEAN) has targeted to secure 23% of its primary energy from modern and sustainable renewable energy sources by 2025. This exact figure and the deadline are also included in Indonesia's National Energy Policy for its national renewable energy sector. This means that quantitatively, Indonesia has deliberately set its national renewable energy goals to be in line with the regional target. The renewable energy sector is a crucial point of concern in ASEAN, and one that cannot afford to overlook growing population levels (along with increased energy demand) and dwindling reserves of indigenous fossil fuels (which equates to larger amounts of imports and, thus, negative external consequences and costs) which have set renewables to be the primary foreseeable alternative for the region. In order to effectively construct the relevant power infrastructure for renewable energy, some estimates state that ASEAN countries together need to invest at least USD 27 billion annually, a total of USD 290 billion by 2025. It is this same intra-regional demand that, in fact, opens up pathways for Indonesia to undertake comparative research with other ASEAN countries to achieve the common goal for renewable energy.

Zooming in on the Indonesian context, the utilization of renewable energy in Indonesia is still relatively small, at approximately 8.66 GW, yet ironically, Indonesia has a fairly large potential for renewable energy, namely 801.2 GW, that can be expanded on and utilized. Among others, this encompasses 75 GW of mini/micro hydro, 32.6 GW of biomass, 532.6 GWp of solar energy, 113.5 GW of wind energy, 18 GW of ocean energy, and 29.5 GW of geothermal energy (The House of Representatives of the Republic of Indonesia, 2016) wherein the largest potential (12,837 MW) is found in Sumatera, and the smallest in Papua (75 MW), 113.5 GW of wind energy, 18 GW of ocean energy and 29.5 GW of geothermal energy (The House of Representatives of the Republic of Indonesia, 2016), wherein the largest potential (12,837 MW) is found in Sumatera, and the smallest in Papua (75 MW).

The utilization of the potential for renewable energy has not yet been optimized for electricity generation. The current total installed capacity for renewable energy in Indonesia is approximately 55,528 MW, which, among others, is comprised of 5.02GWof mini/micro hydro or 7% of total potential; 1.74 GW of bioenergy or 5.3% of total potential; 0.08 GWp of solar energy or approximately 0.01% of total potential; 6.5 MW of wind energy or 0.01% of total potential; 0.3 MW of ocean energy or approximately 0.002% of total potential; and 1.44 GW of geothermal energy or 5% of the total potential.

The development of renewable energy is part of a strategic program of the Indonesian government, and this has to be utilized for the greatest benefit of the people, especially in underdeveloped, outlying, and rural regions (according to Law No. 30 of 2007 on Energy). Both the central and regional governments are tasked to supply energy from renewable energy. Currently, the development of renewable energy refers to President Regulation No. 79 of 2014 on the National Energy Policy (PP KEN). The regulation states that the contribution of renewable energy to the national primary energy mix in 2025 should reach 23%, with a composition of 5% of biofuels, 5% geothermal, 5% of biomass, nuclear, water, solar, and wind energy, and 2% of liquefied coal.

The National Energy General Plan targets the provision of primary energy in 2025 as equivalent to 405 million tons of oil equivalent (MTOE), comprised of 25% of oil fuels, 30% of coal, 22% of gas, and 23% of renewable energy. Renewable energy is targeted for 94 MTOE with a distribution of 69 MTOE (45 GW) for electric power from renewable energy, and 25 MTOE from biofuel, biomass, biogas, and coalbed methane (CBM) at 15.6 KL, 8.3 million tons, 489.9 million m3 and 46 million metric standard cubic feet a day (MMSCFD) respectively. The current 55 GW of national power plant capacity is targeted to increase to 135 GW by 2025. Likewise, power plant capacity from renewable energy, currently 8.7 GW (15.7%), is targeted to increase to 45 GW by 2025; an approximately 33% increase. Among others, this is comprised of geothermal energy power plants, water/mini/micro hydro energy power plants, bioenergy power plants, solar energy power plants, wind energy power plants, and ocean energy power plants, at 7.2, 21, 5.5, 6.4, 1.8 and 31 GW, respectively.

Renewable energy must be developed in order to resolve the matter of dwindling fossil energy sources. Currently, Indonesia is one of the countries with the highest energy consumption growth rate in the world. With this situation, Indonesia is almost a net importer of oil; in 2014 alone, Indonesia imported 203,846,000 barrels of oil (MEMR). Based on data from the 2015 Indonesia Energy Outlook, published by the Technology Assessment and Application Agency, Indonesia's final energy consumption increased from 778 million barrels of oil equivalent in 2000 to 1211 million barrels of oil equivalent in 2013, or an average growth of 3.46% per year. These high levels of consumption have caused faster usage of fossil fuels in comparison to discoveries of new reserves. If renewable energy is not optimally developed soon, the increase in consumption could decrease the availability life of energy in Indonesia.

Being part of the ASEAN, Indonesia is currently at a crossroads as the domestic energy demand continues to grow, bringing new and imminent challenges in the supply of sustainable yet affordable energy. In spite of the target set by ASEAN (23.2% from renewable energy by 2025), current policies in many ASEAN countries enabling the deployment of such forms of renewable energy only reach less than 16.9% of the renewable sources, leaving around a 6.3% gap. To close this gap, every ASEAN country, including Indonesia, is responsible for contributing to the increase in the renewable energy share. The amount of contribution is proportional to the size of the country, the overall in-country energy demand, and the availability of local renewables. Table 5 shows that Indonesia has the highest contribution to the ASEAN target.

Although Indonesia's vast natural resources, on the one hand, have enabled the country to take advantage of any form of renewable energy, be it solar, wind, hydro, geothermal, biomass, biofuel, biogas, among many others, on the other hand, the lack of appropriate government policies to boost the renewable energy deployment has somehow jeopardized the acceleration of renewable energy deployment, to remain in line with the ASEAN's goals.

Bearing in mind the need to fulfill development and utilization targets for renewable energy in Indonesia, this research aims to identify the obstacles and unearth the inner workings of the implementation of the distribution of renewable energy, by enacting a PESTLE policy mapping and stakeholder analysis. The main goal is to dissect and analyze the specific relationships of interest within Indonesia's renewable energy sector and holistically approach the need to adequately cover all relevant terrain in the renewable and sustainable energy sector. This is done by observing agencies or institutions, involved parties, and all relevant stakeholders in the industry with an ultimate goal to better elucidate the various points of dispute among stakeholders and thus come to a recommendation for institutional actors as to how to better promote renewable energy in Indonesia.

Table 5. Contribution toward increasing ASEAN's renewable energy share to 23.2% (IRENA, 2016)

Country	Renewable Energy Shares
Indonesia	+1.7%
Vietnam	+1.3%
Malaysia	+1.0%
Thailand	+1.0%
Philippines	+0.4%

Myanmar	+0.4%
Lao PDR	+0.2%
Singapore	+0.1%
Cambodia	+0.1%
Brunei Darussalam	+0.02%

5.2. Research Approach

This research adopts Political, Economic, Social, Technological, Legal, and Environmental (PESTLE) analysis for its approach. PESTLE analysis is a framework or tool typically used in business and management to analyze the environment they are operating in or are planning to launch new operations in. PESTLE analysis can also be used to monitor the macro-environmental or external factors that play a role in impacting that environment.

The political analysis looks at the extent and impacts of state power on the economy. For example, certain environmental policies may enforce penalties for corporations unable to comply. Economic factors encompass direct impacts on economic capacity, be it of an organization, industry sector/market, or nation-state. Social factors examine the social context of these institutions including, but not limited to, population analytics, demographics, and cultural trends. Technological factors are related to technological advancement, including research and development (R&D), niche technologies, and automation. Legal factors take into account laws and policies, including consumer protection laws, safety standards, and labor laws. Environmental factors are all those critical factors that are conditioned or impacted by environmental issues, geographical location, global changes in climate, weather, etc.

PESTLE analysis has often been used to unravel issues and discourse that are mainly qualitative in nature and as such difficult or rather unsuitable to be resolved quantitatively. In particular, it can be used to analyze and break down various problems more holistically. PESTLE analysis has recently been applied to certain industrial sectors, such as the conventional, fossil-fuel (Yudha *et al.*, 2018; Climent Barba, 2016) as well as renewable (Mytilinou, 2017; Kolios and Read, 2017; Islam and Mamun, 2017) energy industries. By using PESTLE analysis, new strategic policies can be developed to replace and renew policies that are no longer effective or efficient.

5.3. Research Findings

Using PESTLE analysis, the stakeholders of the renewable energy industry will be hereby identified. Stakeholders are referred to as individuals, groups, or institutions that have interests or concerns in the state of affairs within an organization, and typically can affect or be impacted by the organization's activities, targets or policies.

5.3.1. Political

The Energy Law is the legal umbrella for the energy sector in Indonesia. It contains several primary objectives for energy management in Indonesia, as decreed in Article 3, such as energy independence (as the ultimate national objective, notwithstanding Indonesia's situation of a near net importer); ensuring the availability of energy sources; ensuring the management of energy resources is optimal, integrated and sustainable; efficient utilization of energy; ensuring public access to energy; improving industry capacity and domestic energy services in order to be more independent; creation of jobs; and ensuring environmental sustainability.

The Energy Law established the National Energy Board with the authority to plan and formulate long-term energy policies, as outlined in the National Energy Policy. The latest National Energy Policy was approved by the House of Representatives in early 2014. It encompasses targets for renewable energy utilization, elaborated in the National Energy General Plan, that must be completed within one year after the approval of the National Energy Policy. Specifically, the target for renewable energy has been set at 23% of the total energy mix by 2025, and 31% by 2050. This policy requires an increase from the 5% that had been achieved in 2010. These targets update previous targets as part of Vision 25/25; meanwhile, renewable energy targets for 2025 are 2% lower than Vision 25/25. In addition, these new targets do not indicate the existence of nuclear power. These new targets also update the 17% target for renewable energy in 2025, which is an important part of the regulation regarding the National Energy Policy.

Other laws and regulations related to specific sectors complement the legal umbrella, such as foreign investment. Law no. 25 of 2007, for instance, is the primary policy framework concerning investment, which elaborates the principles of the establishment and operation of business activities. This law provides a Negative Investment List, which identifies sectors that are open and closed for private investment. The energy sector is generally open for investment, even though several requirements need to be adhered to, such as:

- Power plants with power capacities smaller than 1 MW are specified for small and medium enterprises and cooperatives;
- Power plants with power capacities between 1–10MWare open for partnership between domestic and foreign companies—even though there are restrictions that necessitate domestic ownership of more than 50%; and
- Power plants with power capacities larger than 10 MW are open for foreign capital ownership by up to 95%.

Various stakeholders are involved in the formulation of renewable energy policies and their implementation; these stakeholders possess several roles in the formulation of renewable energy policies and their implementation (Damuri and Atje, 2018):

1. The Ministry of Energy and Mineral Resources: responsible for policies and regulations in the energy sector. Possesses the Directorate-General of Renewable Energy and Energy Conservation in connection with administrative interests and support for renewable energy and energy efficiency. Manages the electricity sector through the Directorate-General of Electricity and Energy Utilization and supervises the performance of electricity companies, including the State Electricity Company–PLN;

2. National Energy Board: accommodates seven ministries as members and eight non-governmental members, that are responsible for the formulation of the National Energy Policy;
3. National Development Planning Agency (BAPPENAS): economic planning which also encompasses the energy sector;
4. Ministry of Finance: conducts control over government budgets and expenditures, including investments and incentives for renewable energy;
5. Ministry of Agriculture: manages palm oil plantations, etc., that are reserved for raw materials for biofuels;
6. Regional, provincial and regency/municipal governments: play an important role in policy implementation through the development of regulations and issuance of permits; and
7. Other government institutions: The Ministry of Environment and Forestry has an influence on renewable energy, for example through the utilization of forest land for geothermal development; the Ministry of State-owned Enterprises supervises state-owned energy enterprises and influences energy policy implementation; the Ministry of Industry is responsible for issues related to the industry.

However, it needs to be noted that in contrast to practices in various countries including Thailand and the Philippines, there is no independent regulator in Indonesia to resolve disputes and give recommendations/determine prices.

The decentralization reform has caused the reallocation of authorization for investment policies to regional governments, which necessitates project developers to comply with the authorities of both central and regional (decentralized) governments. The decentralization reform, implemented since 2001, has caused a transfer of authority in the policy. Project developers must comply with regulations that have been instated at various levels. Within certain limits that are decreed in the Law on Taxes and Regional Retribution, both provincial government and regional governments can enforce their own fiscal policies related to renewable energy, issue permits for regional electricity companies, as well as determine regional electricity tariffs.

The actors of renewable energy policies are public and private companies which include:

- The State Electricity Company (PLN): owns a large share of power plants, and handles the majority of transmission of distribution.
- Independent Power Producers (IPPs): several currently exist
- Individual IPPs that sell electricity from renewable energy power plants to PLN
- Fuel distributors: includes Pertamina, PT AKR Corporindo, PT Surya Parna Niaga (SPN), Shell, and Petronas
- Biofuel producers

The Ministry of Finance is committed to supporting the development and utilization of renewable energy in Indonesia, in order to assist Indonesia in achieving its ambitious targets for reducing greenhouse gas emissions, increasing its energy security, and facilitating access to energy and regional development. However, although there are several beneficial and potential sources of renewable energy to be developed, Indonesia has not yet succeeded in fully optimizing its development, as seen in Indonesia's energy mix policy. Meanwhile, neighboring countries have succeeded in developing and utilizing renewable energy.

The State Electricity Company (PLN) currently has no obligation to increase the number of renewable energy power plants that are connected to its grid. This means that in outlying regions, thermal generators are prioritized due to faster construction time and ease of integrating them with other sources of energy. PLN projects that, until 2021, only approximately 13% of output will be derived from renewable energy. In fact, even when taking into account the fact that there will be an opportunity to shift to renewable energy outside the generation sector, the company is still struggling to achieve the National Energy Policy target for 2025, namely 23%, for all energy sources.

Explicit targets from PLN for the utilization of renewable energy, consistent with renewable energy targets decreed in the National Energy Policy (23% of the energy mix in 2025 and 31% in 2050), will place added pressure on PLN to attain Power Purchase Agreements (PPAs) for renewable energy. For example, if the current proportion of renewable energy that is used for power generation is maintained (a little above 5%), the 23% target for the energy sector as a whole would mean that 46% of energy input to the power generation sector would have to come from renewable sources, an increase from the current input of 13%. If only 25% of renewable energy is used for power plants, the proportion of renewable energy used for power generation needs to be increased from 13% to 23%. These targets help increase investor trust, in that the PLN possesses a long-term commitment to using renewable energy sources. These targets must be supported by remuneration incentives for senior PLN management, which reflects the importance of target realization.

In many cases, renewable energy would be more expensive to develop than fossil fuels. For this reason, if the PLN desires to achieve these targets, commercial flexibility and more significant price determination are required, ideally under the supervision of an independent regulator. The benefits of efficiency would also help the PLN fulfill its targets of renewable power.

The implementation of renewable energy targets for the PLN is one of the priorities of the Ministry of Finance. In addition, it requires cooperation with other ministries in order to significantly increase the utilization of renewable energy, because the PLN cannot achieve these targets without the correct incentives. Direct costs that are associated with this reform are considered to be low, even though they depend on the commercial flexibility given to the PLN; target realization would require additional public resources.

The Ministry of Energy and Mineral Resources has contrived obligations for the use of biodiesel and bioethanol. Fuel distributors are obligated to mix their products with biofuels, pursuant to Regulation of the Ministry of Energy and Mineral Resources No. 32 of 2008, which was amended by the Letter of Decree of the Ministry of Energy and Mineral Resources No. 25 of 2013.

Fuel distribution for the transportation, industry and commercial sectors is obligated to have biofuel increased by 25% and bioethanol increased by 20% by 2025. In the industry sector, only mining is applicable for this regulation, but the Ministry of Energy and Mineral Resources is planning to encompass more sectors in the future. A 30% biodiesel consumption in 2025 is also required for power plants. It is worth noting that there has yet to be a more comprehensive assessment of the impacts of biofuel production in Indonesia, especially related to both direct and indirect changes in land use due to the increased production of biofuels (Ministry of Finance, 2018).

The percentage of renewable energy (except biomass) in the primary energy supply has been in a stable position, namely a little under 5% for the past few years (Mulyana, 2018); it is still 20% short of the target for 2030, and 26% short of the target for 2050. Indonesia requires significant effort to develop the potential of renewable energy if it desires to achieve the National Energy Policy target.

The percentage of biodiesel use in the transportation sector has increased, but the use of biofuels in other sectors is still low. If biodiesel usage can grow rapidly, the biodiesel targets determined by the Ministry of Energy and Mineral Resources can be achieved. However, conversely, bioethanol production was stopped in 2010 due to inefficient production. Bioethanol was used for the consumer goods industries, but the mixing of bioethanol for transportation was stopped in 2010 because domestic production also ended. Indonesia’s target for 20% bioethanol mixing in 2025 in the transportation, industry, and commercial sectors requires strengthening government support and a significant increase in capacity.

5.3.2. Economic

Although Indonesia is the largest exporter of coal in the world, it still receives challenges in energy security and demand—especially the import of crude oil—which to date has experienced a fairly dramatic increase. Indonesia surpassed Australia as the largest exporter of coal in the world (based on mass) in 2011. However, continuously rising domestic oil consumption, limited investments, and declining production caused Indonesia in 1999 and 2005 to become a net importer of oil and other oil-based products.

The increasing dependence on imported fuels has burdened the financial sector. To date, government policy is to subsidize oil fuel prices to push the expansion of access to energy. However, on the other side, this also causes Indonesia to be vulnerableto price fluctuations in the international market. The 2013 State Budget, as approved by the Budget Committee at a plenary session of the House of Representatives, states that oil fuel subsidies reached Rp200 trillion, with the largest oil fuel subsidies allocatedfor “premium” fuel and diesel. This challenge is prone to enlarging because economic growth requires a large amount of energy.

Increasing renewable energy sources can increase Indonesia's energy security and decrease its dependency on fossil fuels. An increase in renewable energy can reduce dependency on imported oil and price fluctuations, as well as spur the diversification of energy sources and stabilize the trade balance. In this case, without setting aside the increase in demand for transportation fuels, the right incentives, price restructuring, and political commitment for the biofuel industry could stabilize the import of oil fuels, both premium, and diesel, in 2020 (Soerawidjaja, 2013).

The ocean and fishery sector is also deeply affected by the energy issue. This is due to the abundant amount of renewable energy that originates from the ocean. Ocean energy can be exploited in various forms, such as wind power, solar power, current power, wave power, tidal power, and differences in ocean temperature. Nevertheless, to date, these ocean energy potentials have not yet been optimally utilized, and dependence on fossil energy has persisted. Facts show that advances in the optimization of ocean resources are sluggish. Therefore, coastal areas and small islands have the opportunity to become national energy stocks due to the large amount of potential energy contained in the surrounding waters. On the other side, to date, these regions are also pockets of poverty, one factor of this being limited energy supplies.

Several variables support the development of renewable energy, such as:

- The economic prospect of projects—Renewable energy projects must be able to bring in levels of return that are adjusted to risk. Currently, there are several renewable energy technologies in Indonesia that do not give good levels of a return due to unsupportive policies. Energy subsidies are the primary obstacles to fulfilling Indonesia's renewable energy targets. Although aimed at increasing the production of renewable energy and reducing the proportion of energy originating from fossil fuels, energy price policies are counterintuitive to this objective. When energy subsidies decrease, at least the reduction of these subsidies is allocated to price externalities for energy consumption, such as carbon dioxide emissions, especially in power plants, which in the future will support renewable energy. Through the National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK), implemented by the National Development Planning Agency, Indonesia has committed to reducing its greenhouse gas emissions. From the aspect of cost-effectiveness, the best way to achieve this is through price determination. The government has taken important steps through cooperation with the Partnership for Market Readiness, and by undertaking preparatory work to introduce market instruments to support mitigation activities. Calculations for carbon prices from energy production and energy price usage, which can potentially be initiated in the electricity sector, would make renewable energy sources more competitive as well as increase their absorption. Cutting back on energy subsidies is a high-priority policy reform for the Ministry of Finance (Putera, 2018). The Ministry of Finance directly controls subsidy budgets, including those used to cover fuel and electricity. Therefore, even with major political challenges, Indonesia is in a strong position to gradually remove its energy subsidies in the mid-range. The utilization of renewable energy will receive a positive impact because the market will achieve a new equilibrium wherein conventional energy sources are no longer unjustly benefited. In addition, cutbacks on energy subsidies would also reduce public expenditures.

- Access to financing—Apart from the level of profit from renewable energy projects, the investment will not be realized if there is only a small amount of remaining capital. Not only does financing need to be available with fair levels of interest to reflect investment risk, but there also needs to be accessible to the proper types of financial services, as well as a consistent tolerance level on risks, with a risk profile that underlies investments. This is known to be a specific challenge for Indonesia, where many financial institutions are unwilling to invest in what is perceived as new and risky technologies (WBCSD Energy and Climate, 2018).

5.2.3.1. Fiscal Incentives in the Development of Renewable Energy

The primary fiscal incentive for renewable energy was regulated through the Regulation of the Ministry of Finance (PMK) No. 21/PMK.011/2010. This regulation gives tax incentives for all renewable energy producers and all assembly and imports of machinery required for production.

These incentives were given through case-by-case consideration and included terms related to income tax, value-added tax, import duty, and taxes paid by the government. Terms for income taxes encompass:

- 30% reduction in net income out of the total investment (for 6 years, at 5% per year);
- acceleration of permanent asset depreciation used in renewable energy production, which varies depending on the asset type;
- a 10% income tax for dividends received by non-residents in renewable energy production (or in accordance with tax agreements);
- compensation for loss, which helps producers absorb losses for several years before receiving income, thus reducing tax payment for 5 or 10 years, with the possibility of consideration of further extending compensation periods; and
- exception from Article 22 of income tax, for the import of machinery and tools required for renewable energy production.

This decree was implemented in compliance with Government Regulation No. 1 of 2007, which was later updated through President Regulation No. 52 of 2011. Furthermore, Regulation of the Ministry of Finance No. 21/PMK.011/2010 gives exceptions for value-added tax and import duty, as well as several taxes covered by the government:

- exemption of value added tax applies to the import of machinery and tools, but does not include spare parts required by companies for the utilization of renewable energy sources;

- exemption of import duty for capital and machinery used for renewable energy production can be requested if it is included in the master list. This only applies if these goods are not available in Indonesia, or if the product specifications in Indonesia are not suitable. This exemption applies for two years and can be extended for one more year, and the government can choose to pay certain taxes or duties if the given sector is included in annual laws on the State Budget.

In 2012, Rp815 billion from income taxes in the geothermal sector was paid by the government. Government Regulation No. 52 of 2011, implemented through the Regulation of the Ministry of Finance No. 144/PMK.011/2012, gives the same incentives with clearer procedures, but only for certain sectors. This regulation gives incentives for companies investing in sectors/regions that are deemed to possess high national priority and encompasses 129 types of investment (52 types of investment in certain sectors and 77 types of investment in certain regions), which include:

- power plants: new energy technologies including hydrogen, CBM, coal gasification and liquefaction, renewable energy technology including hydro, solar, wind, and ocean energy;
- geothermal energy: all geothermal exploration, drilling, and electricity generation; the processing of organic waste in palm oil factories to produce biogas as supplies, in order to produce electricity or hydrogen; and
- the bioenergy industry (biodiesel, bio-oil and bioethanol).

The Directorate-General of Taxes gave approval to facilities, based on recommendations from the Head of the Investment Coordinating Board (BKPM). The Directorate-General of Taxes will release decisions of approval within ten days subsequent to receiving recommendations from the Investment Coordinating Board—to date, these terms are the only time limitations for the approval process. Approved terms for tax facilities can be used in the fiscal year wherein investors have realized at least 80% of investment plans, after the Directorate-General of Taxes pays its field audits and releases letters to verify that these investments have been realized. After the tax facilities have been given, receivers of these facilities must submit periodic reports (on the due date of these taxes) on investment realization, production, and details on permanent assets, ownership, transfer, and replacement. If companies have fulfilled the requirements for these two regulations, they can choose to make a request to use regulation No. 144/PMK.011/2012 or No. 21/PMK.011/2011.

5.2.3.2. Repairing and Stabilizing the Price Regime of Renewable Energy

The incessantly shifting nature of price regimes for renewable energy has created market uncertainty. Often-occurring changes in price regimes have madecurrent policy frameworks for prices less transparent, sustainable, and consistent. Thishas caused investors to be uncertain about investments. A primary example of this is the price policies for geothermal and mini-hydro energy; meanwhile, there is always intense discussion on whether or not the system will change back into a competitive tender system with price ceilings. Likewise, the hope for an increase in feed-in tariffs (FITs) for mini-hydro developers has caused developers to postpone investment.

For renewable power generation facilities below 10 MW, the current FITs regime seems to be widely successful and needs to be maintained in accordance with potential. For renewable power generation facilities above 10 MW, several price guidelines for different technologies need to be implemented. These guidelines need to give price estimations that are hoped to later be approved and included in PPAs.

To promote fiscal sustainability, price ranges and prices within these ranges need to consider the economic feasibility of renewable energy technologies, which can be calculated by comparing generation prices from renewable energy technologies with generation prices from conventional technologies that are usually found in certain locations (avoidable generation prices).

The lack of price guidelines, except for those related to geothermal energy, has caused difficulties for stakeholders to have conviction in the development of electricity sales for currently existing projects, due to uncertainty over generally prevailing prices. Consequently, this leads to disregarding a number of renewable energy opportunities from the energy supply side. At the same time, the official FITs system is likely to be difficult to maintain, given the different conditions throughout the country–differences that will be highlighted for larger facilities that produce larger output.

Price control is needed so that efficiently operating generators can be expected to fulfil rational targets for internal rates of return (IRR). Financial models that support price calculations also need to be publicized so that stakeholders can assess the existing assumptions.

*5.2.3.3. **Budget Composition of Ministries for the Renewable Energy Sector***

As an attempt to increase the utilization of renewable energy, the government allocated Rp2,116 trillion in the 2016 Revised State Budget, with a utilization target for renewable energy amounting to 18,600 MW in 2019. Funding for the development of renewable energy that is derived from the 2016 State Budget will be focused on solar energy. The number of solar energy power plants that will be built by the government will significantly increase, with a targeted total capacity of solar energy power plants of 18,359 kW, increasing from 5070 kWp from the previous year.

Apart from being allocated for the construction of solar energy power plants, other types of infrastructure that will be built in 2016 are 6122 kWp of micro-hydro energy power plants, 850 kilowatts (kW) of wind energy power plants, 1500 kW of urban waste energy power plants, 3000 kW of waste energy power plants, 1000 kW of seaweed bioenergy power plants, 5000 kW of bio-oil energy power plants, 23,100 kiloliters (kl) of biofuel tanks, and public lighting in 10 cities.

In its development, the government has conducted budget efficiency for ministries/agencies and regional transfers for the 2016 fiscal year. Budget cutbacks for ministries/agencies are initiated because targets for state revenues in the 2016 Revised

State Budget are likely to be unable to be realized. In this case, the Ministry of Energy and Mineral Resources is one ministry/agency that has experienced budget cutbacks of Rp900 billion. In fact, government data state that the institution that has suffered the largest budget cutback is the Directorate-General for Renewable Energy and Energy Conservation.

The budget for the Directorate-General of Renewable Energy and Energy Conservation, previously Rp2.1 trillion, has been reduced to Rp1.7 trillion–a cutback of almost Rp400 billion. Nevertheless, the government still attempts to maintain strategic programs that are primary priorities in the sector of renewable energy and energy conservation. For example, the government did not cut back on the Bright Indonesia Program to electrify outlying villages that are still without electricity. Cutbacks in the Directorate-General of Renewable Energy and Energy Conservation are aimed primarily at projects that are impossible to realize by 2016. An example is the construction of micro-hydro energy power plants in Papua, at the border between Indonesia and Papua New Guinea, which to date have not received Environmental Impact Assessment licenses. In addition, the budget for waste energy power plants in Bali has also been abolished due to preparatory difficulties. The Directorate General of Renewable Energy and Energy Conservation stated that the fairly large budget cutback was due to the cancellation of a project to install solar panels on the rooftops of three airports–Medan, Bali, and Makassar.

5.3.3. Social

In 2011, 66 million people (approximately 27% of the entire population) did not have access to electricity, and 102 million people (approximately 42% of the entire population) relied on traditional biomass for cooking (International Energy Agency, 2013). With the large dispersion of islands and geographical size, Indonesia faces an extraordinary challenge in the process of connecting its residents to electricity access.

The operational costs for diesel generators in rural areas in Indonesia were estimated to be in the range of Rp3000–9000/kWh (Zymla, 2012). Conversely, a 100 kW solar energy power plant on an island in eastern Indonesia only produces costs of Rp2800/kWh. A hybrid system that combines solar energy power plants and diesel generators could become an interesting choice for a number of regions in Indonesia.

Several studies indicate that this system gives a more reliable supply of electricity with smaller costs compared to only relying on solar energy power plants (with a lower level of reliability). This potential has been acknowledged and inserted by the PLN into the development plan for constructing solar energy power plants in 1000 islands, which targets the installation of 620 MW of solar energy power plants in outlying regions by 2020, by creating mini and micro-networks that combine diesel generators, biomass and solar panels (Sofyan, 2018).

The current national unemployment level is at 5.13%, a significant improvement when compared to 11.2% in 2005 (Prakoswa, 2018). However, the majority of these new jobs are of low quality. The International Labor Organization (ILO) estimates that approximately 60 to 63% of workers are categorized as vulnerable workers, casual workers, outsourced workers, and family workers. These types of work generally do not give adequate social protection and do not fulfill the minimum wage standards of workers or give opportunities for social dialogue. Therefore, the ILO, with support from the government, has promoted green jobs, which are environmentally sound and friendly jobs. More precisely, green jobs will help reduce the consumption of energy and raw materials, catalyze the decarbonization process of the economy, protect and improve the ecosystem and biodiversity and minimize the production of waste and pollution. In addition, the ILO has declared that a job can be categorized as a green job if the job is adequate, productive, and contains the opportunity to receive ample wages, social protection, and social security for workers and their families, as well as the right to conduct a social dialogue.

The geothermal and biomass energy subsectors currently provide around 5000 green jobs. In addition, the majority of the 331,000 green jobs in the manufacturing sector are connected to the production of renewable energy components, whereas the majority of the 187,000 green jobs in the construction sector are connected to the installation and assembly of renewable energy power plants. Renewable energy has a large potential to spur the growth of quality jobs in Indonesia because green jobs involve labor-intensive work. For example, solar panels require 3 to 10 times the number of workers compared to crude oil and coal; wind and biomass energy power plants can absorb up to three times the number of labor-intensive workers compared to conventional resources (Kammen *et al.,* 2004).

Important aspects of job creation from renewable energy need to be considered, therefore, include: (1) the rigidity of the labor market, meaning that there are short-term costs, such as training, so that workers are able to undertake jobs that are related to renewable energy; (2) the high level of labor intensiveness indicates that the productivity of labor is low; and (3) the high cost of renewable energy has a negative effect on competition and price, although this is less of a concern if renewable energy replaces the more costly conventional energy.

5.3.4. Technological

The development of the renewable energy sector requires reliable and cost-effective technology (Tran and Smith, 2017). For this reason, there needs to be a form of cooperation with related parties in order to adequately develop this sector. With rapid advances in renewable energy technology, there needs to be an improvement in the determination of renewable energy prices in accordance with economic conditions so that the sector can compete with fossil energy prices. In addition, there needs to be a joint commitment between the government and business actors, and support from the national financial sector in order to build capital-intensive, technology-intensive, and high-risk infrastructures for renewable energy. This can be done through support in the form of fiscal incentives, investment guarantees, regulation assurances, and subsidies, as well as special attention to isolated regions and frontier islands that directly border other countries.

To date, the majority of technology for the development and utilization of renewable energy is supplied by foreign parties. Several renewable energy technologies has been mastered, such as small to medium-scale power plants and biogas technology for non-electricity needs.

One of the main obstacles to the development of renewable energy is government policies that give a relatively small number of subsidies and incentives for investors in green technology. Subsidies are still too small compared to subsidies for primary fossil energy, whereas investment costs for renewable energy are still high due to minimal domestic components being available for this technology. Consequently, the value of renewable energy is uncompetitive compared to fossil energy. Existing conditions result in a relatively long and uncertain period for profit, which means that investments in renewable energy are unattractive for both national and foreign investors. There are currently a number of technology developers and manufacturers of renewable energy systems in Indonesia; however, they are vocal in expressing their concern about the lack of incentives from the government, especially regarding the pricing schemes for renewable and sustainable energy.

5.3.5. Legal

Energy in Indonesia is regulated by Law No. 30 of 2007. This Energy Law also established the National Energy Board with the authority to plan and formulate long-term energy policies, as elaborated in the National Energy Policy. The latest National Energy Policy was approved by the House of Representatives in early 2014 and encompasses targets for the utilization of renewable energy. Other laws and regulations complement the legal umbrella connected to specific fields, such as foreign investment. Law No. 25 of 2007 is the main policy framework related to investment, which elaborates the principles of establishment and operations for business activities.

Connected to the regulation of the utilization and tariffs for renewable energy, the following are several legal frameworks that are targeted by existing policy implementations.

5.3.5.1. Geothermal Energy

The government has given special technological incentives and general incentives, including FITs and PPA standards. The Regulation of the Ministry of Energy and Mineral Resources No. 17 of 2004 on Power Purchasing from Geothermal Power Plants and Geothermal Steam for Geothermal Power Plants has instated the tariff ceiling for electricity generated by geothermal power plants, as a guideline for prices determined in PPAs after the tendering process. In this new regulation, tariffs are determined based on location and Commercial Operation Date plans, in order to give assurance and anticipate the effects of inflation. In 2015, the tariff ceiling ranged from USD 0.118 to USD 0.254 depending on location and will increase to between USD 0.159 and USD 0.296 by 2025 for projects with subsequent Commercial Operation Dates. This regulation revised the regulation of 2012, which bases tariffs on project locations, whether or not these projects are connected to medium- or high-voltage grids.

This regulation also still mandates the PLN to develop the PPA model for geothermal projects. There is a special revolving fund facility, the Geothermal Fund Facility (GFF), aimed at reducing risk related to geothermal exploration. The Government Investment

Unit manages funds that aim to reduce early-stage development risk by giving support to the collection of high-quality data and information on new and potential geothermal locations. This project development stage usually uses up between USD 15–25 million over roughly three years, which encompasses at least 10% of total capital expenditures (ESMAP, 2013). The GFF aims to reduce these obstacles through anticipated services and products; primarily, as stipulated in the Regulation of the Minister of Finance No. 3/PMK 011 of 2012, the GFF provides:

- up to USD30 million of loans for explorations at the interest rate of the central bank, paid only if a location is proved to be productive; funding is given to the regional government (which has possibly conducted external tendering for the subsequently proved locations) and qualified private investors; and
- information and data which have been verified by reputable consultants, with real costs and an additional 5% margin, paid for by interested parties.

Cumulative funding that was available throughout 2011–2013 amounted to more than Rp3.1 trillion (approximately USD217 million). Since then, several funding proposals are in advanced stages, although no real cash has yet been discharged. The Indonesian Geological Body is responsible for subsidized data collection, although no surveys have yet been conducted. Several stakeholders feel that there is uncertainty over the type of products that will be offered by this facility, as well as the interest rate.

5.3.5.2. Solar Energy

Regulation of the Minister of Energy and Mineral Resources No. 17 of 2013 determined the allocation and price of solar energy. The tender for capacity quotas for solar energy, which will require the PLN to purchase, has been in effect since then. In April 2013, 172.5 MW was tendered with a tariff ceiling of USD0.25/kWh, to be increased to USD0.30/kWh if project developers use more than 40% of local components. Successful bidders must show that they fulfill various administrative, technical and financial conditions; bids with the lowest price for the offered capacity will win. The PLN offers a 20-year PPA standard for successful bidders. A number of developers have expressed concern over the ceiling price, which currently is too low for developing feasible projects, especially when taking into consideration the possibility that many solar panel projects require foreign funding; their concern also includes the poor grid quality, especially outside the Java and Bali grids, which can complicate the transmission of solar-powered electricity that is generated into the grid.

The PLN plans to offer a net metering program for rooftop solar panel generators up to 1 MW; this program has not yet been officially instated nor regulated through ministry-level regulations. Currently, the Regulation of the Board of Directors of the PLN No. 0733 of 2013 only stipulates the basic principles. This allows homeowners to generate electricity from solar panels and transmit their surplus production into the grid, with compensation in the form of reduced electricity bills for customers. The net excess of production is not compensated. Reports (Rauch, 2014) show that net calculations would only be attractive for customers who pay the highest tariffs. Stakeholders expect that this policy would take at least one year before it is officially instated.

5.3.5.3. Small-Scale Renewable Energy Power Plants

Regulation of the Ministry of Energy and Mineral Resources No. 4 of 2012 stipulated that the PLN must purchase electricity from renewable energy projects that have capacities below 10 MW. FITs are available for biomass and biogas technologies (stipulated in Regulation of the Minister of Energy and Mineral Resources No. 27 of 2014), urban solid waste (through the stipulation of the Regulation of the Ministry of Energy and Mineral Resources No. 19 of 2013) and other renewable energies, with prices ranging from Rp970–1798/kWh for low-voltage grids (average tariffs taken into account) and Rp880–1450/kWh for mid-voltage grids (average tariffs taken into account).

5.3.5.4. Biofuels

Biofuel producers can benefit from subsidies and tax reductions (Damuri, 2018); biofuel producers receive Rp3000/l and bioethanol producers receive Rp3500/l. In addition, biofuel producers fulfill the requirements for value-added tax restitution, but this can only be claimed retrospectively.

The government has released a price formula for biodiesel and bioethanol for fuels. Fuel distributors such as PT Pertamina are required to apply this price formula in their tenders for biofuels. The Decree of the Minister of Energy and Mineral Resources No. 2185K/12/MEM/2014 stipulates that biodiesel prices be as large as those of Middle Oil Platts Singapore (MOPS) plus 3.48%.

5.3.5. Environmental

Indonesia has shown the international community its plans for reducing emissions. The National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK) has committed to reducing emissions in 2020 by 26% below the emissions produced from business-as-usual (BAU) with domestic funding, and 41% below BAU if international support is available. RAN-GRK is a working framework for supporting mitigation activities, including within the agriculture, forestry, and peatland, energy and transportation, industry, and waste processing fields. Its objective is to become a guideline for the central government and regional governments, the public, and economic actors in conducting planning, implementation, supervision, and evaluation of the action plan to reduce greenhouse gas emissions.

Reducing emissions from the energy sector will be important in realizing the formulated objectives. Although emissions from the electricity and transportation sectors only contributed 170 tons of emissions in 2005, i.e., less than 10% of total emissions, these sectors are projected to increase their emissions by more than 8% per year and by approximately 1250 million tons, or almost 40%, in 2030. This projected growth is faster compared to other emission sources.

Several renewable energy options can reduce emissions with relatively low costs. Geothermal energy could give a reduction of approximately 35 MtCO2 per year with costs amounting to only a little above USD10/tCO2. In addition, the potential to reduce costs from renewable energy sources, including solar panels, biomass, and wind, is quite significant, even though these alternatives are on average more expensive, with costs ranging between USD20–30/tCO2.

Renewable energy resources could also contribute to the improvement and advancement of environmental and human health. Toxic gas emissions and various particles discharged from fossil fuel combustion have negative impacts on human and environmental health in many large cities. Like in other large cities in Southeast Asia, the level of PM10 (particulate matter that is 10 micrograms per cubic meter or less in diameter) in the majority of large cities in Indonesia has surpassed the limit of air quality, as specified by the World Health Organization (WHO). The WHO projects Indonesia's condition, which reflects the lack of policy focus on improving the quality of air in cities. In total, air pollution has caused approximately 32,300 deaths every year from 2004 to 2015 (UNEP, 2015). In 2011, Indonesia contributed 1,290,000,000 tons of CO2e, making it the 6th largest greenhouse gas emitter in the world and contributing 4.5% of total global greenhouse gas emissions (International Energy Agency, 2015).

5.4. Discussion

Based on the PESTLE analysis, we can see in a more holistic way how certain aspects of PESTLE dynamically impact each other. For example, one of the issues pertinent to the legal aspect is the lack of an overarching national law or regulation that will serve as a dedicated legal umbrella for all subsidiary regulations on renewable energy. At present, the Energy Law of 2007 is still too broadly defined and lacks the specific level of elucidation necessary for a truly comprehensive policy on renewable energy. A Renewable Energy Bill is currently being formulated in the House of Representatives, but at present, the lack of such a legal precondition indirectly reflects and leads to a fragile and haphazard political state of renewable energy policies, limited to the ministerial level.

These temporary and fleeting policies give a worrying signal to investors of a political regime that is still unsteady in its policy-making. On a further note, it is interesting to note that in the context of Indonesia, the relative academic lacuna in the literature concerning supply chain management for renewable energy is also mirrored by that of a technocratic lacuna of supply chain management planning for renewable energy. We see how ASEAN frameworks have already incorporated crucial infrastructure planning for regional energy flows, such as the ASEAN Power Grid and Trans-ASEAN Gas Pipeline. However, a similar approach at the national level—one that involves a comprehensive geographic mapping and projecting of renewable energy supply chains and infrastructures throughout the Indonesian archipelago—is still lacking. National technocratic discourse on renewable energy primarily still revolves around pricing policies—an unavoidable bone of contention—vis-à-vis the fossil fuel industry.

While the economic aspect of Indonesia's nascent renewable energy industry is one of the most pressing concerns, it can also be perceived as an early checkpoint into a more advanced and technical discussion. Renewable energy development does not only encompass project economics, but also "technical constraints, supply chain capacity [italicized here for emphasis], social effects, namely to amenity and aesthetics, and environmental impacts" (Cucchiella, 2013). This "supply chain capacity" translates into abstracting the flows of (renewable) energy and material into modular yet robust upstream-to-downstream planning. Such a supply chain management that specifically serves to accommodate the renewable energy sector must also be holistic in nature (Tjahjono *et al.*, 2017). Bearing a similarity to the multifaceted PESTLE analysis, a promising candidate model is the Sustainable Supply Chain Management (SSCM) (Seuring and Müller, 2008), which not only views supply chains in the context of the environment but also expands their scope to encompass social and ethical issues. PESTLE analysis thus cements the groundwork for a national SSCM framework, as such a framework must necessarily take into account the various stakeholders involved in the entire sector.

Reflecting on the national planning process on renewable energy, it is vital to implement the previous PESTLE analysis on a comprehensive stakeholder analysis of renewable energy interest groups and actors. An analysis of stakeholders that are involved in the development of renewable energy in Indonesia reflects the implications of implemented policies, as attempts to increase the role of renewable energy. This means that existing conditions become points of reference in the formulation of new policies for developing renewable energy. In connection with the development and utilization of fossil energy, as elaborated in the same method of analysis, patterns of policy implementation in the development of fossil fuels could be indicators in policy formulation for improving the management of renewable energy. Learning from the success of the implementation of fossil energy policies, which was then later implemented to improve the management of renewable energy, is a fairly effective method, and also strengthens arguments for undertaking the transformation from fossil energy to renewable energy.

It should be noted that identifying the relevant stakeholders in Indonesia's renewable energy sector—which inevitably ties in with state actors as well as the fossil fuel sector—is a crucial prerequisite for any serious recommendation for future national policy. In addition, through a PESTLE analysis, it is possible to better highlight the crisscrossing and overlapping sectoral interests within the energy sector as a whole.

For example, as mentioned in Section 3, Indonesia requires renewable energy not only to advance toward a low-carbon economy in the face of dwindling fossil fuel reserves but also to generate green jobs (the social context) and safeguard a sustainable environment for future generations. These points of concern necessarily encompass specific subsectors and stakeholders; promoting green jobs in renewable energy development is related to the national labor conditions and relevant stakeholders, which in turn then stems back to the underemphasized financial value of renewable energy sources in comparison to current fossil fuel standards. Through PESTLE analysis, a better understanding of the interrelationship of these ostensibly different aspects is juxtaposed and highlighted through stakeholders. In this PESTLE analysis, various stakeholders who contribute to the development and utilization of renewable energy have been identified and their interconnectedness is shown in Table 6.

Table 6. Stakeholders of the renewable energy industry in Indonesia

Stakeholders	Political	Economic	Social	Technology	Environment	Legal
Commission VII of the House of Representatives of the Republic of Indonesia	√				√	√
Budget Committee of the House of Representatives of the Republic of Indonesia		√				
President of the Republic of Indonesia	√				√	
Ministry of Energy and Mineral Resource	√	√				
Ministry of Labor			√			
Ministry of Environment and Forestry					√	
Ministry of Agrarian Affairs and Spatial Planning		√				
Ministry of Transportation			√			
Ministry of Maritime Affairs and Fisheries					√	
Ministry of Finance		√				
Ministry of Trade		√		√		
Ministry of Industry		√				√
National Development Planning Agency		√				
Corruption Eradication Commission						√
Finance and Development Supervisory Agency						√
Supreme Audit Agency						√
Bank Indonesia (Central Bank)	√	√				
Constitutional Court						√
Investment Coordinating Board		√				
Directorate-General of Electricity and Energy Utilization		√				
Directorate-General of Renewable Energy	√					√
Directorate-General of Customs and Excise of the Ministry of Finance	√					
State-owned Enterprises	√	√				
Regionally-owned Enterprises	√	√				
National Banks		√				
Regency Government				√	√	
Provincial Government				√	√	
PLN (State Electricity Company)		√				
Independent Power Producers	√		√	√	√	
Investors	√					
NGOs					√	
Indonesian Chamber of Commerce	√	√				
Public			√			

5.5. Conclusions

The development and utilization of renewable energy have been assessed from the aspect of stakeholders using a PESTLE analysis, in an attempt to identify and correlate existing overlapping and cross-sectoral stakeholder interests in Indonesia's renewable energy sector. Existing policies are still in their infancy and subject to significant upgrades, given that the renewable energy industry is still quite minimal, especially in the current conditions of falling oil prices. The lack of suitable policies has subsequently exposed the stakeholders and players in renewable energy to various risks–the greatest ones being economic and technological. The ability of the policymakers in Indonesia to identify these risks and mitigate them is indeed the key to success.

In the future, it is hoped that the government can formulate a breakthrough policy to improve the renewable energy sector, such as by giving ease to investors in the renewable energy sector, so as to enable the effective and efficient supply chain management of renewable energy. In addition, it should be noted that Indonesia's targets for renewable energy—23% primary energy mix by 2025—are synchronous with that of the ASEAN as a whole. Therefore, Indonesia should acknowledge and capitalize on this common regional goal and attempt to undertake cross-comparative research programs for national development. A PESTLE analysis for stakeholders in the renewable energy sector will also help cement a starting point for formulating a framework for a comprehensive national supply chain management for renewable energy.

Chapter 6: Paper 3 - Stakeholders' Recount on the Dynamics of Indonesia's Renewable Energy Sector

Paper accepted 8th May 2021 and published in Energies: Yudha, S.W., Tjahjono B., Longhurst, P., (2021) Stakeholders' Recount on the Dynamics of Indonesia's Renewable Energy Sector, Energies 2021, 14, 2762; https://doi.org/10.3390/en14102762

Abstract

The study described in this paper uses direct evidence from processes applied for the developing economy of Indonesia, as it defines the trajectory for its future energy policy and energy research agenda. The paper addresses the research gap to make explicit the process undertaken by key stakeholders in assessing and determining the suitability, feasibility, and dynamics of the renewable energy sector. Barriers and enablers that are key in selecting the most suitable renewable energy sources for developing economies for the renewable energy development have been identified from extensive analyses of research documents alongside qualitative data from the Focus Group Discussions (FGD). The selected FGD participants encompass the collective views that cut across the political, economic, social, technological, legal, and environmental aspects of renewable energy development in Indonesia. The information gained from the FGD gives insights into the outlook and challenges that are central to energy transition within the country, alongside the perceptions of renewable energy development from the influential stakeholders contributing to the process. It is notable that the biggest barriers to transition are centered on planning and implementation aspects, as it is also evident that many in the community do not adhere to the same vision.

Keywords: focus group discussion; sustainability; renewable energy development; Indonesia; geothermal

6.1. Introduction

The development of alternative renewable energy sources in Indonesia is of paramount importance not only to fulfill the ever-increasing energy demand in the country but also to contribute to reducing the carbon emission, combating the devastating effects of climate change, and achieving the Nationally Determined Contributions (NDC), that is to reduce the carbon emission of 29% with its own effort or 41% with international aid by 2030 (Gielena *et al.,* 2019).

The renewable energy sector plays an important role to reduce carbon emissions. Indonesia is currently aiming to increase the share of renewable energy to become 23% by 2025 within the National Energy Mix (Gielena et al., 2019). Due to its unique geographical contour features, Indonesia hosts an enormous potential for renewable energy from various sources. The country is undergoing a journey to seek the most suitable renewable energy sources to focus on.

By 2020, Indonesia has only reached halfway towards the 2025 renewable energy target. The development of renewable energy in Indonesia is currently suffering from many obstacles ranging from technical to policy aspects that have significantly hindered its progress. Exploiting renewable energy sources requires a careful appraisal of the potential key predicaments and enablers of its development. Identifying and focusing on a specific type of renewable energy source is therefore deemed essential to mitigate the risks of failure. Analyzing the progress of existing development of renewable energy can be done using various ways, for example, by pulling together insights from all relevant stakeholders, which in the case of Indonesia, broadly encompass both state and market players.

In order to acquire a more comprehensive and dynamic outlook, it is necessary to move from the preliminary stakeholder analyses to probing some crucial information directly from the sources, i.e. the stakeholders. This paper, therefore, aims to obtain the stakeholder's recount of the assessment and of the suitability, feasibility, and dynamics of the renewable energy sector in Indonesia, which will ultimately pave the trajectory of our future agenda of research. To ascertain the execution of transparent, repeatable, and credible research outcomes, the following research questions have subsequently been set.

RQ1. According to the stakeholders' recount and outlook, what are the main key challenges, barriers, or problems associated with renewable energy development in Indonesia?

RQ2. What are the stakeholders' views on the potential key enablers for renewable energy development in Indonesia?

RQ3. What is the most suitable renewable energy type to be developed in Indonesia?

RQ4. Depending on the type of renewable energy selected, what can be proposed to support the development of that particular renewable energy in Indonesia?

Such information gathering can be done via interviews, surveys, or focus group discussions involving key stakeholders of renewable energy in Indonesia, with an ultimate goal to collate the previously disparate information, experience, and decision-making processes.

The structure of this paper is as follows. Section 2 set out the theoretical foundation of this work by elaborating the various works not only pertinent but also relevant to this work. This way, gaps in the existing literature that this work will address can be clearly identified. Section 3 details how the research will be conducted, including the data collection method and analysis. Sections 4 and 5 discuss the findings and their implications for the body of knowledge. Section 6 concludes the paper by identifying a set of proposals that lays down a pathway for the development of renewable energy in Indonesia.

6.2. Related Work

A successful transition of energy sources from fossil fuel to renewables requires careful evaluation in terms of the planning system and renewable energy selection (Gielena et al., 2019). Evaluating the renewable energy system can be a complicated process. Such an evaluation process requires appropriate tools that support the data analysis of the availability of the renewable energy sources, selection criteria, and methods used in the selection process (al Irsyad *et al.*, 2017).

6.2.1. Renewable energy selection and decision making

Many researchers have carried out the evaluation and selection of the most suitable renewable energy in many countries and different scenarios. There are many decision-making methods that can be applied for renewable energy selection. In this section, we will have a look at some of the previous research on renewable energy selection in different countries, using different research approaches.

One of the many popular methods that can be used for assessing the most suitable renewable energy to develop, is a mathematical modeling method. Gonçalves da Silva (2010) (Gonçalves da Silva, 2010) used a conceptual framework and a set of mathematical models to evaluate the energy balance of energy conversion technologies for renewable energy development in Brazil. The result showed that wind energy was the most favorable renewable energy source to develop in Brazil, while solar power was the least suitable for development. Another method that can be applied forevaluating and selecting renewable energy is Multi-Criteria Decision Making (MCDM)method. Emir (2014) performed the selection of renewable energy for small islands using the MCDM method, applicable for Malta, Cyprus, Cuba, Jamaica, the DominicanRepublic, and Singapore. They considered cost analysis, technical issues, social issues,locations, and environmental issues as the criteria for evaluation. Solar energy was deemed the most suitable renewable energy to invest in and develop in small islands.

Analytical Hierarchy Process (AHP) remains the most popular method to use for selecting the most suitable renewable energy in many different countries. The research conducted with this type of method typically employed a variety of criteria, such as technical performance and efficiency, ecological integrity, economic expedience, sustainable development, socially-responsible operation, and technological innovativeness. Based on these criteria, different countries have different results in regard to the most suitable renewable energy (Sliogeriene, 2013; Ahmad and Tahar, 2014; Li-Bo and Tao 2014; Madhuri et al. 2017)

6.2.2. Renewable energy selection in Indonesia

Indonesia is one of the countries with abundant potential for many different types of renewable energy development, therefore selecting the most suitable type of renewable energy to develop is very vital for the energy transition. Despite having quite a few choices for renewable energy with abundant potential, research that is specific to the selection of the most suitable renewable energy in Indonesia is still lacking.

Rumbayan and Nagasaka (2012) used the Analytical Hierarchy Process (AHP) method to identify and rank the most suitable renewable energy in Indonesia, using the level of availability of renewable energies as the primary consideration. Three types of renewable energy were analyzed for this study, including solar energy, wind energy, and geothermal energy. The result shows from this study that geothermal is the best criterion, followed by solar and wind alternatives. Tasri and Susilawati (2014) used the Fuzzy Analytical Hierarchy Process (F-AHP) to determine the most appropriate type of renewable energy to develop in Indonesia. This research used several selection criteria, such as sustainability, economic, social, and technological point of view. They evaluated renewable energies for this research including solar energy, hydropower, geothermal energy, wind energy, and biomass energy.

Based on the previous research, it is evident that the quantitative approach, especially the Analytical Hierarchy Process (AHP), remains the most popular method to use for renewable energy selection. While the quantitative approach can provide tangible information by generating numerical data, which is beneficial for statistics, it also has certain limitations. A quantitative approach may not be able to provide a deep understanding and the underlying reasons behind those numbers. The qualitative approach can provide an extended explanation and reasoning behind a certain dataset. Collating a deep understanding and explanation provided by qualitative analysis can be very important. In the case of renewable energy selection, this information can be used not only as an input for evaluating and selecting the best renewable energy for an area, but it can also provide thoughts, opinions, and essential information that can be useful for potential follow-up research, for example, research on policy development, which involves many parties and stakeholders. Therefore, for this research, the qualitative approach is preferable to the quantitative approach, and it is chosen to evaluate and select the most appropriate renewable energy technology in Indonesia.

6.3. Methodology

In terms of renewable energy evaluation and selection, the quantitative approach appears to be the most popular method used as it offers a number of benefits, notably providing a more tangible data analysis thus preventing perceived biases (Krueger and Casey, 1994). The qualitative approach, on the other hand, takes the benefits of the flexibility of qualitative data and the level of feedback that is capable of explaining phenomena that are difficult to be quantified (Krueger and Casey, 1994). In the context of renewable energy selection, many unquantifiable parameters need to be considered, for instance, appropriate technology, political impacts, capacity building, stakeholder engagement, community acceptance, etc. (Sovacool, 2013). Obtaining a deeper understanding of these unquantifiable parameters in renewable energy development can be done by incorporating the roles of stakeholders within this industry. Yudha and Tjahjono (2019) performed a stakeholder analysis to map out the actors in the renewable and sustainable energy sector in Indonesia using PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) analysis. Each stakeholder encompasses specific areas, for example, the Ministry of Energy and Mineral Resources covers the political and economic aspects, while the public covers the social aspect. According to this study, there are numerous stakeholders in the renewable energy sectors, that can provide their thoughts and opinion in regard to renewable energy development in Indonesia. However, incorporating all this input using a quantitative approach would be less effective than using a qualitative approach.

This research employed a qualitative approach based on a Focus Group Discussion (FGD) as a primary research method, complemented by the document analysis (Figure 6). This method is selected since it allows the researcher/interviewer to question several individuals systematically and simultaneously (Kvale, 1996) or in this case the stakeholders in sustainable and renewable energy. FGD, also known as the group interviewing method can be based on structured, semi-structured, or unstructured interviews (Rahman, 2017; Kvale, 1996) and can generate data (Carey, 1994; Stevens, 1996; McDaniel, 1996) that can be both descriptive and explanatory (Nyumba *et al.*, 2017). This method is frequently used as a qualitative approach to gain an in-depth understanding of complex issues (Miles and Huberman, 1994). Krueger (1994) warned that there are advantages and disadvantages to conducting an FGD. The clear advantage of FGD is that it can capture real-life data within a social environment, has high flexibility, high face validity, and a speedy result, in addition to its low cost. However, when conducting FGDs, care must be taken when moderating it, as it can potentially be a problem when there are differences within the group, in which case it could lead to a great deal of difficulty in analyzing the outcomes. Following the primary group discussion, document analysis was performed to formulate the policy priorities on Indonesia's renewable energy. The process of policy development and confirmation in this FGD is shown in Figure 6.

The group size can range from as few as four to as many as 12 people within a conducive environment to engage in a guided discussion of a certain topic or issue (McDaniel and Bach, 1996), in this case, prospects and challenges in Indonesia's renewable energy development. The participating subjects are selected on the basis of relevance to the topic under study. In addition to this, special consideration is given to the role of the researcher/interviewer, as the moderator in the focus group process. As Babbie (2010) comments: "*In a focus group interview, much more than in any other type of interview, the interviewer has to develop the skills of a moderator*". Controlling the dynamic within the group can be a challenge.

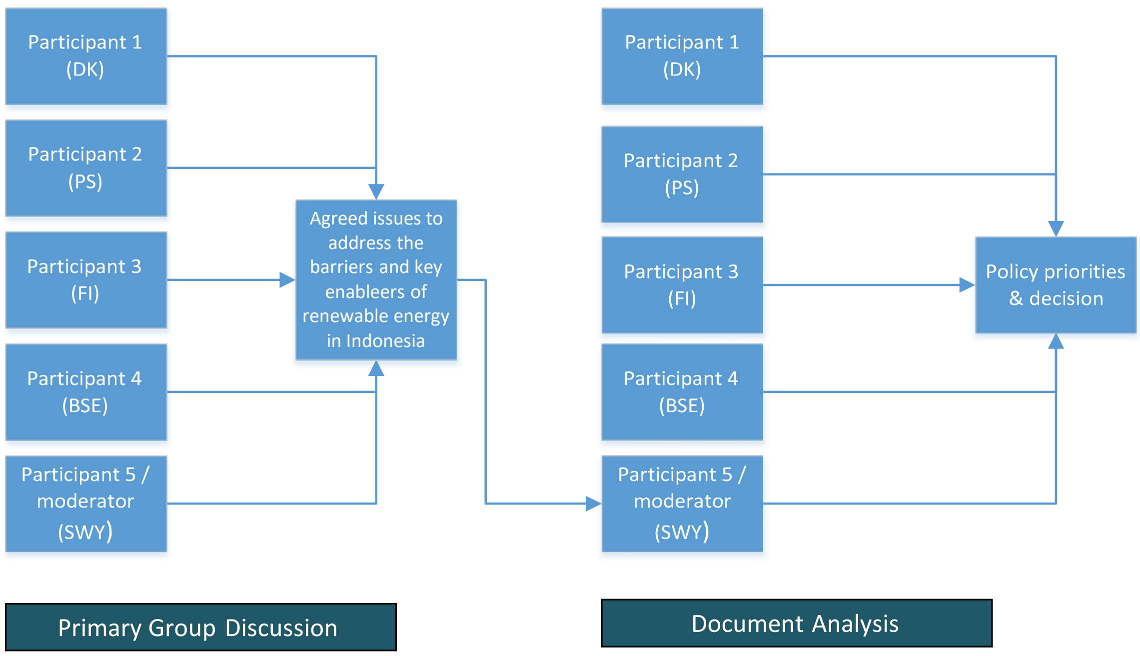

Figure 7. Flowchart of primary group discussion and document analysis

The FGD incorporated four participants as the sample population, plus one of the researchers working on this paper, who acted as the moderator. The participants were chosen due to their expertise and experience in renewable energy development in Indonesia. Their representation encompasses the collective view of stakeholders identified by Yudha and Tjahjono (2019), cutting across the political, economic, social, technological, legal, and environmental (PESTLE) aspects of renewable energy development in Indonesia (Table 7). Without necessarily reducing the essence of the perspective of PESTLE analysis, the numbers of the participants were purposely kept to a level in order to keep the forum conducive. This purposive sampling of participants was ensured to cater to the range of expertise at hand, to enable the document analysis that was also used as a basis of the analysis during the FGD.

The unit of analysis chosen, consistent with the previously applied PESTLE method of analysis, is the stakeholders' outlooks and responses with regard to renewable energy development in Indonesia. In this research, the FGD also served other purposes, such as developing specific insight and practical knowledge, as well as obtaining feedback and propositions for renewable energy development, based on each stakeholder's perspectives.

In addition, the FDG was also open to members of the press, including the House of Representatives official press, covering the political, environmental, and legal aspects, to inquire and provide input to the participants during the questions and answer session.

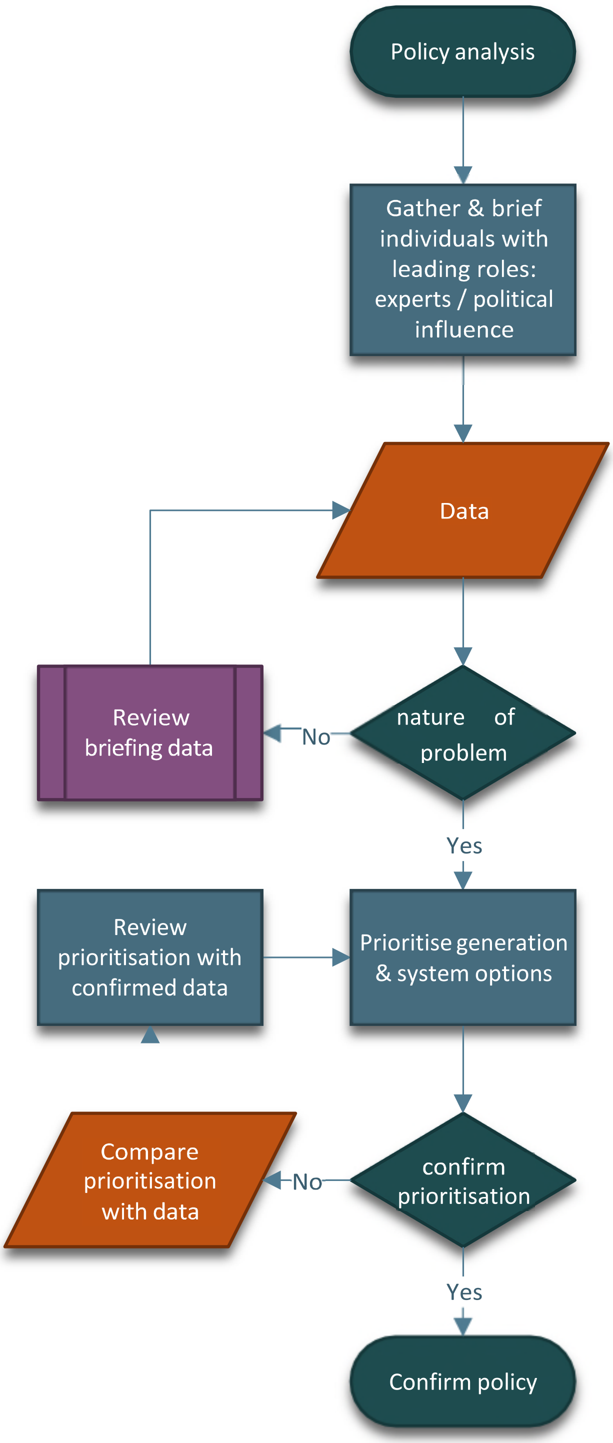

Figure 8. FGD process of policy development and confirmation

This section may be divided into subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

Table 7. FGD participants mapping and their respective sectors (modified from Yudha and Tjahjono (2019)).

Participant	Representing	Political	Economic	Social	Technology	Legal	Environment
DK	Ministry of Energy and	✓	✓				

	Mineral Resources						
PS	Special Task Force for Upstream Oil and Gas Business Activities		✓		✓		✓
FI	Indonesian House of Commerce	✓	✓			✓	
BSE	Member of public			✓			
SWY	House of Representative, the Republic of Indonesia	✓	✓				✓

6.4. Findings

The FGD began with an introductory opening by the moderator, who introduced the participants and laid out the overall theme of the discussion. Each of the participants was then given the time and the opportunity to share their recounts and outlooks on renewable energy in Indonesia, including the challenges associated with renewable energy development in Indonesia, and the propositions for moving forwards and overcoming these challenges.

Following the discussion, all the participants proceeded to analyze each type of renewable energy in Indonesia, specifically wind, solar, ocean, biomass, hydropower, and geothermal. Using multiple secondary information and research documents as a basis of the analysis, the group then appraises these energy sources in terms of their potential, current development, limitations, and development opportunities. The main objective was to map out the progress of each type of renewable energy development. Unlike the previous session, in this session, every participant was allowed to voluntarily give their opinion and constructively rebut each other in an open discussion. The outcome of both sessions will be used to pave the way forward to deciding the most suitable and feasible renewable energy type for further development in Indonesia.

6.4.1. A snapshot of renewable energy development in Indonesia

Following the introduction, the moderator described the precarious situation of Indonesia's inevitably declining fossil energy supply, and the urgent need for a transition from fossil to renewable energy. Using this opening statement, the moderator then invited the FGD participant to voice out their views.

First to speak was DK, Secretary to the Director-General of New and Renewable Energy of the Ministry of Energy and Mineral Resources, representing the Director-General of New and Renewable Energy, RM. In general, DK outlined the Indonesian government's readiness in developing Indonesia's renewable energy sector, as well as provided the government's perspectives as to the current situation and challenges of the industry. For example, DK highlighted the imperative of developing renewable energy in Indonesia, not only from the aspect of promoting environmental consciousness but also as a crucial element in the realization of Indonesia's sorely needed and ambitious national electrification goal.

"*Renewable energy is driven by its environmental aspect, given its environmentally friendly and clean nature. For us, aside from the environmental aspect (there is a presidential regulation already in effect concerning emissions), renewable energy contributes to reducing greenhouse gases*". - DK

According to DK, what was deemed important from the point of view of energy and mineral resources was the ultimate goal of developing renewable energy is to help accelerate energy access for the large population of the nation who live in far-flung areas from the capital.

"*In Java, Madura, or Bali, electricity is sufficiently supplied by PLN [State Electricity Company], but if we travel to the eastern regions and islands, there are still many of our brothers and sisters who have not yet benefited from electricity*." - DK

Recent data indicated there are 12,500 villages in the eastern Indonesia regions have been electrified, but this figure is far from ideal as there are at least 2,500 villages still without any access to electricity. Responding to the queries from the audience, he further stated:

"*We will carry out our village electrification program until 2019. The Director-General of New and Renewable Energy has been tasked by the Minister of Energy and Mineral Resources to assist in the provision of access to electricity sources*". - DK

Furthermore, he mentioned that it has been promulgated in Government Regulation No. 79/2014, also known as the National Energy Policy, that renewable energy is targeted to comprise 23% of the primary energy mix by 2025. However, Indonesia currently has only 7% of renewable energy in its energy mix. To make up for the relatively significant difference in renewable energy composition within the energy mix, DK highlighted key renewable energy potentials as well as several ongoing government strategies for renewable energy development. These include, among others, Indonesia's 11,000 hectares of oil palm plantation which can be used for biodiesel.

The second speaker was PS, Deputy of Finance and Monetisation at the Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas). PS made several key observations, firstly concerning present obstacles in Indonesia's oil and gas industry stemming from the global decline of oil prices. As a representative of the government regulatory body for oil and gas, PS also interestingly noted that

"...[the oil and gas] business has become over-regulated. Our oil and gas management practices are currently under scrutiny. Are our current regulations capable of providing incentives to bring results to our oil and gas resources?" - PS

Concerning renewables, PS posed important statements from his observation:

"…considering the fact that major corporate players in fossil-fuel energy have been uniformly and consistently diversifying their portfolios into the renewable energy sector, is our capability in managing the fossil energy business transferrable to the renewable energy business?" -PS

This was subsequently responded to by other participants proposing differing views. Nonetheless, they in the end reached a collective view, acknowledging that although the technicalities differ, long-time corporate players have arguably brought along their managerial and economic know-how of the fossil energy industry to leverage their business activities in renewables, particularly geothermal. It can therefore be concluded that by learning from Indonesia's experience in managing fossil fuels, the country is hopeful to use its wealth of experience and know-how to manage the renewable energy sector. Exactly how these are going to be managed indeed needs further elaboration and thoughts.

Following PS, the third speaker was FI from the Renewable Energy Division of the Indonesian Chamber of Commerce (Kamar Dagang Indonesia or Kadin). FI expressed his disappointment with the present state of Indonesia's renewable energy sector. He then proceeded to identify the primary barrier to uptake from the private sector:

"*Kadin is pushing forward in the renewable energy sector, but what is the obstacle? Regulation!*" - FI

Referring to tenurial disputes over several renewable energy projects, particularly geothermal, FI also mentioned that the development of renewable energy in Indonesia is often *"...hampered by NGOs, indigenous communities, and others."*

FI also hit on the barriers to renewable energy development that cause the slow uptake by investors, mentioning that

"…feed-in-tariffs must also be fairer and involve stakeholders, not suddenly prescribed. This is indeed a problem in the renewable energy sector; as initial technologies are exorbitant, investors choose to wait and see." - FI

Lastly, FI sees the need for a strong local manufacturing and supply chain, so that components for renewable energy would be cheaper to produce domestically rather than imported.

The final speaker was BSE, an observer of the renewable energy industry. BSE opened by hypothesizing that energy sustainability is linearly correlated with welfare and the wealth of a nation. BSE proceeded to outline his solutions:

"The question that follows is how to satisfy the large amount of energy needed by low-cost, clean energy sources? We cannot do business as usual. We must push for breakthroughs." - BSE

He asserted that electrification consists of three large components: power generation, transmission, and distribution. Therefore, it would be sensible to clearly split the responsibilities between those components. BSE argued that this was necessary to stimulate healthy competition and foster core competence.

"PLN [State Electricity Company] should only focus on transmission and distribution of electricity, giving an opportunity for other parties, including private sectors to 'play' in the renewable energy generation arena, especially clean, large-scale power generation. There are only three options: hydro, geothermal, and nuclear." - BSE

The moderator concluded this first session with a summary of key findings and lessons learned.

Finding 1: *There remain problems in both the planning and implementation stages of renewable energy, mainly due to the [lack of] regulations, but this does not necessarily mean that both stages do not adhere to the same vision.*

Finding 2: *Lessons learned from the oil and gas sector should later be transferred over for the future development of renewable energy, so as not to fall into the same pitfalls that impede and create inefficiency in the oil and gas sector.*

6.4.2. Renewable energy types in Indonesia

The second session of the FGD analyzed in detail several documents, mainly government policy analyses of various renewable energy sources. The moderator led the discussion (following the method illustrated in Figure 6) and asked the participants of FGD to comment on the suitability of the six sources of renewable energy, and come up with a collective decision on the most suitable renewable energy source that Indonesia should develop going forward.

In order to hit 23% of renewables in the primary energy mix by 2025 and 31% by 2050, Indonesia has been attempting to achieve the targets (Ministry of Energy and Mineral Resources (MEMR) of Indonesia, 2017). Renewables accounted for just 15.7% of the country's primary energy mix by 2019, while fossil fuels accounted for 87.6% in 2019 (MEMR, 2017; State-owned Electricity Company, 2019). Indonesia is a host to a variety of renewable energy sources, namely wind energy, solar energy, ocean energy, biomass energy, hydropower, and lastly geothermal energy. The development of each type of energy source varied, and the FGD looked at each type of renewable energy, how they have been developed in Indonesia, and the challenges that each energy type encounters, with an expectation that the group came up with a collective view on the preferred renewable energy type.

6.4.2.1. Wind energy

Wind energy is the type of energy that uses the conversion of wind speed into a useful source of power, and it can be used for multiple purposes, such as electricity generation, mechanical power wind turbines, water-driven wind turbines, or ship propellers (IESR, 2019). Wind energy is considered to be one of the renewable energy innovations, as it does not contribute to air pollution or greenhouse gases, and has a slight impact on the climate.

The use of wind power as an energy source in Indonesia has great potential for further growth, especially in coastal areas where the wind is quite abundant. According to previous research, Indonesia has an estimated total potential for onshore wind energy of 9.3 GW. With a range of wind speeds between 2 and 6 meters per second, Indonesia is suitable for installing small-scale (10 kW) and medium-scale (10–100 kW) wind-driven generators (IESR, 2019). Indonesia has installed five units of windmill generators across the country each with a capacity of 80 kW and seven other units with the same capacity have been established in four places, North Sulawesi, the Pacific Islands, Selayar Island, and Nusa Penida, Bali (Hasan *et al*, 2012). Several wind-based power plants, namely Sidrap, Tanah Laut, and Jenepoto, have currently been under construction, while the ones in Sukabumi, Banten, and Bantul, are currently being considered to be placed under construction planning (Hasan *et al*, 2012).

Price is one of the biggest obstacles that Indonesia faces in installing wind energy. The initial cost of developing wind energy is very high, particularly with the use of offshore wind turbines. IRENA suggests that it costs about US$3-US$4 million per megawatt (MW) to install offshore wind turbines compared to geothermal power plants which cost about US$2-US$3 million (IRENA, 2019).

However, wind energy has some issues associated with the geographical locations that jeopardize the consistency of supply, as pointed out by a participant,

"… indeed, we know that it [wind] is a promising form of energy in our country [Indonesia]. But its intermittent nature makes it hard to provide electricity 24/7. It generates unstable and fluctuating electricity, and a good source of wind power is only available in certain parts of our country [Indonesia]". - FI

Another difficulty is caused by the availability of other renewable energy sources available in Indonesia, such as geothermal, hydropower, biomass, and solar, which makes the cost analysis method challenging to carry out (DEN, 2019).

6.4.2.2. **Solar energy**

Solar energy is a source of renewable energy that uses the power of the sun to produce electricity. Globally, solar energy has the fastest and highest growth compared to the rest of the renewable energy types. It is currently considered one of the most promising sources of clean, renewable energy and has greater potential than any other energy source to solve the world's energy problems.

As Indonesia is a tropical country situated on the equator line, the country has an abundant capacity for solar energy. Many areas of Indonesia have very strong solar radiation with average daily radiation of approximately 4 kWh/m2 (Indonesia Energy Outlook & Statistic, 2006). According to the report from the Directorate of New and Renewable Energy (Ditjen EBTKE) in 2018, Indonesia has the potential to harness solar energy of up to 207.8 gigawatts peak (GWp) (IEEFA Asia Pacific, 2019). However, as of 2019, Indonesia has only installed 25.19 megawatts (MW), which is mainly used to meet energy demand in rural areas, including lighting for public service areas and places of worship (Hasan *et al.*, 2012). The Institute for Energy Economics and Financial Analysis (IEEFA), an energy research institute, has reported that about 48 MW of solar power is currently under construction and about 326 MW is under construction planning (IEEFA Asia Pacific, 2019).

Indonesia is still far behind other ASEAN countries in solar power utilization. Thailand has 2.6 GW of installed solar capacity and the Philippines has 868 MW of installed solar capacity (PwC, 2019). Vietnam is also working on an expansion of more than 3,000 MW in solar and wind power capacity by 2019 and 2020 and Malaysia is targeting an additional 3,000 MW in 2020 (Dang, 2017).

There are many obstacles to the implementation of solar energy in Indonesia. One of them is the high prices of solar cells, including solar panels, inverters, batteries, wiring, installation, and battery storage (Dang, 2017). This situation not only impacts financial institutions to provide resources to implement this program but also limits local communities' confidence and interest in using this system due to its exorbitant costs. Because of that, the implementation of this program is highly dependent on government funding. Despite its huge potential, a solar panel is very dependent on sunlight to effectively capture solar energy. Even though it can capture energy during cloudy and rainy days, it can also give measurable technical effects on the energy system. Due to its intermittent nature, solar energy might be more suitable for a household scale, but it might not be the best option for a larger scale energy system. This is emphasized by one of the participants:

"It's fortunate that being on the equator, we [Indonesia] are blessed with warm climate all year round. We have the potential to develop solar energy. However, much like the wind, it is intermittent and it [solar] will require storage systems to generate electricity after daylight". - DK

6.4.2.3. Ocean energy

Ocean energy sometimes referred to as marine energy, is a type of energy that is carried by the ocean's elements, such as the ocean's tide, wave, salinity, and temperature. Each one of these elements can be exploited as different types of energy, namely tidal energy, wave energy, salinity gradient energy, and ocean thermal energy conversion (OTEC). Wave energy converts ocean waves to produce electricity, while tidal energy harvests the power that was produced during high and low tides (Purba *et al.,* 2014). Salinity gradient energy can generate electricity due to the difference in salt concentration between freshwater and seawater (IRENA, 2014). OTEC converts the temperature difference between cold seawater and warm surface seawater, typically at around 800 to 1,000 meters of depth, to produce electricity (Siahaya and Salam, 2010).

Indonesia is the world's largest archipelago with 70% of its area covered by ocean, thus it has the largest potential for ocean energy. According to research from the Indonesian Ocean Energy Association (INOCEAN), the potential of ocean energy resources that can be exploited is around 92.2 GW. The majority of its potential is coming from OTEC, with 43 GW of resource potential, followed by tidal and wave energy with 4.8 and 1.2 GW of resource potential respectively. Despite its considerable amount of potential for harnessing ocean energy, the installed capacity for ocean energy is only 0.3 MW or 0.002% of the total energy use (PLN, 2019). As of 2020, ocean energy is still in the stage of Research and Development and this type of renewable energy has yet to be commercially developed in Indonesia (Hasan *et al.*, 2012).

"…unlike solar and wind, ocean energy can provide electricity throughout the entire day since it does not require the sun or the wind to harness electricity. Nevertheless, ocean energy is still rather far from the full commercialization in Indonesia". - DK

6.4.2.4. Biomass

Biomass energy is one of the types of natural renewable energy that is generated from organisms, and mostly comes from farm crops and residues, forest waste, farm foods, and animal waste (Fungenzi, 2015). Biomass is the only renewable energy that can be used to generate three types of fuels: liquid, solid, and gas. Proper biomass energy development could also reduce not only energy issues but also waste management issues.

As an agricultural country, the potential of biomass resources in Indonesia is relatively abundant. According to the report from the Directorate of New and Renewable Energy in 2018, Indonesia has the potential of harnessing 32.6 GW of biomass energy (PLN, 2019). However, only 167.54 MW of biomass energy in Indonesia has now been properly exploited. Currently, Indonesia's estimated total biomass production is around 146.7 million tons, which is equivalent to 470 gigajoules per year (GJ/y) (Abdullah, 2006). Most of the biomass energy source comes from the rice residue and rubberwood, which contributes to 150 GJ/y and 120 GJ/y respectively (Abdullah, 2006). These are followed by sugar residues (78 GJ/y), palm oil residues (67 GJ/y), and other types of residues (20 GJ/y) (Abdullah, 2006). Such biomass sources can help supply both heat and electricity to rural households and sometimes small-scale industries.

Bioenergy, in general, has faced similar problems as other renewable energy sources. One of the primary issues is the high investment cost for bioenergy installations, as claimed by one participant:

"…while Indonesia has an abundant amount of biomass energy that can be utilized to generate liquid, solid, and gas, it is still expensive to invest in and the lack of support from financial institutions has hindered its growth". - DK

Part of the reason is that bioenergy deployment feasibility studies are mostly not attractive for bank loans (Sapuan and Aditya, 2018). From the perspective of technology, the reliability and efficiency of the existing technology for biomass energy are still lower than fossil fuels (Sapuan and Aditya, 2018), hence hindering bioenergy development.

6.4.2.5. Hydropower

Hydropower energy is a type of renewable energy source that extracts energy from flowing water, to produce electricity. As a potential future source of energy, hydropower has become an increasingly attractive choice for small capacities of renewable energy. This type of energy, as well as other renewable energy sources, are clean energy sources as they emit a negligible amount of greenhouse gas.

Hydropower is one of Indonesia's large-scale, commercially viable, renewable energy sources. According to the report from the Nippon Koei, the hydropower capacity in Indonesia is projected at around 26,321 MW. Currently, the installed capacity of hydropower is 4,938.64 MW from various hydropower plants all across the nation; the large-scale plants are operated by the state-owned electricity company (PLN) and many small-scale plants are owned by small enterprises. According to the 2019-2028 Electricity Supply Business Plan issued by PLN, it has been reported that 5,956 MW of hydropower capacity is currently under construction scattered in many places, whilethe new 16,027 MW of potential capacity has just been built as of 2018, and is considered for being placed under construction planning (PLN, 2019).

To date, hydropower energy in Indonesia is still the most established and the most utilized small-scale renewable energy source, particularly in rural areas. Hydropower systems provide unique operational versatility in that they can adapt to sudden fluctuating demand for electricity, which means that they can be tailored to satisfy market demand (Erinofiardi, 2016). Hydropower is also able to provide support for the development of other renewable energy sources, for example, its storagecapacity and flexibility can be the most cost-effective and efficient to support the utilization of intermittent renewable energy sources such as solar and wind energy. Hydropower can generate vast quantities of energy and the price is relatively stable, asit is less affected by market price fluctuations such as oil and gas, although the price advantage is proportional to the capacity of the plant, i.e. relatively small capacity. There is, however, a major drawback of hydropower development as it is heavily dependent on geographical features (i.e. large rivers) to generate electricity. Therefore,large-scale utilization of hydropower is only limited to certain places with specific geographical features, making micro-hydropower -with a lower price advantage- a more viable option, as asserted by FI:

"…no, the majority of them [sources] are only suitable for small-scale power plants. Only certain areas of Indonesia have the full capability to generate large-scale electricity". - FI

Geothermal energy is the type of renewable energy that uses heat derived from the sub-surface of the Earth, which can be transmitted in the form of hot steam, hot water, or a mixture of both forms. Nowadays, it has been one of the most important alternatives for energy sources with significant growth potential. It not only provides alternative energy but also helps to reduce the effects of global warming and the risks to public health due to the use of conventional energy sources, as well as our dependence on fossil fuels. Geothermal energy may be used for district heating purposes or harnessed to produce renewable electricity, depending on its characteristics. The lower enthalpy type of geothermal is mostly suitable for direct use (e.g. room heater, tourism, agriculture/agro-industry, and fisheries), while medium to high enthalpy type of geothermal can be used for generating electricity, which is typical for the regions with active tectonics (Nasruddin *et al.*, 2016). Indonesia has varying types of geothermal energy that can be utilized for both direct heating and generating electricity (Surya *et al.*, 2010).

Indonesia is one of the countries in the world that falls on the "Ring of Fire", which traversed around the edges of the Pacific Ocean and is responsible for most active volcanoes and earthquakes. Due to its tectonic setting, Indonesia is a host to most of these active volcanoes, which accounted for 117 active volcanoes in total (BellHa, 1979; Manalu, 1988). These active volcanoes are distributed in Sumatra, Java, Nusa Tenggara, Sulawesi, and Maluku. Consequently, Indonesia has a considerable amount of high heat flow, which makes it one of the countries with a large potential for geothermal energy.

According to studies, Indonesia has the world's largest geothermal energy potential, accounting for about 40% of the world's potential or approximately 28,617 MW (Nasruddin *et al.*, 2016). Most of these potential energy resources and reserves are distributed in several regions in Indonesia. Sumatra and Java have currently the highest total potential energy, which accounts for 12,760 MW and 9,717 MW respectively (Nasruddin *et al.*, 2016). The rest of the potential is distributed in many other regions, namely Bali, Nusa Tenggara, Sulawesi, Maluku, Kalimantan, and Papua (Nasruddin *et al.*, 2016; Surya et al., 2010).

According to FI, geothermal, when compared to other sources of renewable energy except nuclear, can guarantee the provision of electricity at a stable rate throughout the entire year without being affected by weather patterns and conditions. He further added:

"The cost of geothermal technology in the future will be increasingly competitive and is expected to continue to fall. Thus, the optimization of geothermal energy in Indonesia is vital in helping the government achieve its renewable energy target and reduce greenhouse gas emissions". - FI

Despite having a considerable amount of potential, geothermal energy utilization in Indonesia, especially for electricity generation, is not quite optimal. Currently, the geothermal energy in Indonesia that has been utilized for generating electricity is 2,130.6 MW (PSDG, 2019), making it the second-largest country with installed geothermal capacity, putting the Philippines in a third-place with 1,868 MW of installed capacity and following the United States with 3,639 MW of installed capacity according to ThinkGeoEnergy report. Most of the installed geothermal capacity in Indonesia comes from the geothermal power plant in Java, which accounts for a total of 1,253.8 MW of installed capacity, followed by Sumatra with 744.3 MW, Sulawesi with 120 MW, and lastly, Nusa Tenggara with 12.5 MW of installed capacity

[46]. The development of geothermal energy is still yet to be done in many other regions in Indonesia.

Up until 2019, the utilization of geothermal in Indonesia was only 2,130.6 MW out of 56,509.53 MW, or around 3.77% of the total energy utilization (PLN, 2019). This number is still very small compared to the Philippines that have already used 44.5% of its energy use from geothermal energy [28]. There are a few factors that havebeen the reason for Indonesia's lagging development of geothermal energy utilization. Exploration and resource commercialization of geothermal utilization is a costly process, in addition to a small market for the resource. Limited investment financing schemes for geothermal development have also contributed to the stagnation in this industry.

According to PS, Deputy of Finance and Monetisation at the Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas),

"…geothermal development has a very unique characteristic since it includes the upstream phase, similar to that of oil and gas sector". - PS

He further underlined the transferability of management know-how from the fossil fuel economy to the geothermal business. In essence, the pitfalls of Indonesia's oil and gas industry retrospectively provide lessons learned for the management of geothermal. Although these two sectors are quite different in terms of the nature of the commodities involved, PS believes that the technical management know-how from the oil and gas industry should be transferred and refined.

Finding 3: *Geothermal stood out during the FGD as the most promising renewable energy source that Indonesia should develop.*

Finding 4: *Exploration of geothermal utilization needs an intervention from the government in the form of financing schemes, so as to alleviate the burden of upfront investment.*

6.5. Discussion

Indonesia has a few choices when it comes to developing renewable energy sources. Having the capability to develop all types of renewable energy to a point where it cannot only fulfill the whole country's energy demand but also fully liberate the country out of fossil fuel dependency, would be an ideal case. Although achieving this would require long years of huge effort and costly processes, having this ideal scenario would lead us to significantly contribute to reducing carbon emissions and increasing the economic growth of the country. Reflecting on the participants' feedback reported during the FGD, we can glean from this dialogue that different stakeholders have alluded to differing inherent interests and points of view based on their respective institutions. The differences are mainly related to the key enablers and barriers of renewable energy development in general leading to the selection of the most suitable renewable energy to focus on future development.

6.5.1. Barriers and key enablers

Indonesia has tremendous renewable energy capacity which is still underutilized by the Indonesian power sector. The long dependency on fossil fuels, particularly coal, has proved difficult to break as the image of coal as cheap energy while renewable sources remain expensive technologies. Although some steps toenhance renewable energy have been placed many years ago, the Indonesian renewables sector has yet to take off.

The development of renewable energy sources in Indonesia has not beenwithout any barriers, as it has encountered quite a few challenges from operational, to financial regulatory challenges. The operational challenge is mostly related to the nature of each type of renewable energy source, which includes the availability and reliability issues. Financial challenge is mostly related to the exorbitant initial cost of installation and it has been one of the major hurdles for the development of renewableenergy, regardless of the type of renewable. Lastly, the regulatory challenge is viewedas the primary obstacle in the energy transition and renewable development, especiallyfor the private sector, which hampers the development process. Having analyzed the barriers, the obstacles are quite evident in both the planning and implementation stageof renewable energy development. However, this does not necessarily mean that both stages of development do not adhere to the same vision. Therefore, regulation and policy refinement is indeed necessary, and thus become the most important keyenablers, as it allows us to tackle multiple present barriers effectively.

According to the stakeholders' points of view, some of the important key enablers are classified as follows, so identifying these enablers is of paramount importance for the transition to renewable and sustainable energy technologies.

1. The availability of an institutional framework of national targets and development plans that transcend organizational leadership is one of the most important initial key enablers, as it reflects the government's commitment to renewable energy endeavors. The imperative development of renewable energy in Indonesia needs to be viewed not only from the aspect of promoting environmental consciousness but also as a crucial element in the realization of Indonesia's sorely needed and ambitious national electrification goal, as well as the national primary energy mix as a tangible target for now, which is achieving 23% of renewables in the primary energy mix by 2025 and 31% by 2050.
2. Focusing on the forward-thinking scheme of supply chain management for the manufacturing of renewable energy is viewed as another significant key enabler. Such a scheme needs to consider how local industries can effectively source the materials and technology needed for the Indonesian-made renewable energy supply and market. Especially in the presently liberalized global economy, Indonesia needs to strengthen its local leverage in terms of the competitiveness of goods and trade. The ultimate and obvious aim of this

endeavor is to make local renewable energy supplies and technology cheaper to produce domestically than to import.

3. Refining the regulation and policy is one of the most vital key enablers for the energy transition. The courage of institutional and organizational are essential to break down outdated and inadequate regulations, as well as to design new regulations and policies that can accommodate the interests of all relevant stakeholders.
4. Focusing on the clean, large-scale types of renewable energy for power generation, for instance, hydropower and geothermal energy. Nuclear power as another new energy source has also been considered and is still categorized as a viable option, considering all the relevant safety and technical concerns being put in place.

6.5.2. Selection of renewable energy type for development

Focusing on developing the most suitable type of renewable energy would be an important first step toward better utilization of renewable energy. Here we will have a look at each type of renewable energy and use a comparative analysis to decide the most suitable renewable energy to focus on developing in Indonesia, considering the limitation and opportunities that each type of renewable energy has to offer, according to the expertise' inputs during the FGD.

Ocean energy is the least developed renewable energy in Indonesia. Despite having a huge potential for developing ocean energy, no commercial-scale ocean power plants now exist as it is now still under the research and development stage. According to the 2019-2028 Electricity Supply Business Plan issued by PLN, there has been no technology manufacturer for ocean energy that has proven its reliability to operate commercially for at least 5 years. The development will be reconsidered once the technology is mature enough to generate electricity on a commercial scale.

Wind and solar energy can provide not only alternative sources for renewable energy, but they can also give us a number of environmental benefits, as they produce a negligible amount of carbon footprints. However, the development of these renewable energy sources has major drawbacks. The initial deployment process of wind or solar energy can be quite costly and it hinders the investment due to its exorbitant costs. Even though both solar and wind energy should be seen as low-risk investments with potentially major returns, they are hefty investments nonetheless. Moreover, both wind and solar energy are intermittent by nature, as they are heavily dependent on the weather. Therefore, the electricity generated by these renewables is most likely to be fluctuating and it can potentially become a problem. Fluctuating supply of electricity is not a reliable power supply, as it is not best suited for providing base-load. Furthermore, fluctuating electricity, particularly in the solar panel system, may have measurable effects on the power instrument. Therefore, relying solely only on solar and wind energy may not be the best option for now, especially for a massive commercial scale, but they may be suitable for smaller-scale development.

Biomass energy development is currently in a better state than previous sources of renewable energy now that the Minister of Energy and Mineral Resources Regulation (Permen ESDM) Number 50 of 2017 has been issued. Not only does it contribute to meeting the energy demands, but proper biomass energy development also allows us to cope with better waste management. However, the expensive upfront cost to get the power plants up and running has been the most common issue in developing renewables, which also applies to biomass energy. In addition to the exorbitant upfront cost, biomass development would require additional costs associated with the extraction, transport, and storage of biomass prior to the generation of electricity. Biomass energy plants also require quite a bit of space with a constant supply of biomass resources, which might not be suitable for big cities. Therefore, the development of biomass energy may be more suitable for underdeveloped, isolated regions in the country.

Hydropower is by far, the most established and the most utilized renewable source of energy. Hydropower has been operating on a commercial-viable, massive scale. Due to its operational flexibility, hydropower can adapt to sudden fluctuating demand and it can be tailored to satisfy market demand, thus making it a very reliable source of energy. Its development has been very steadily growing every year, with numerous undergoing projects. However, being heavily dependent on geographical features (i.e. large rivers) to generate electricity, has been a major drawback of hydropower development. Large-scale utilization of hydropower is only limited to certain places with specific geographical features. Therefore, focusing more on a different type of renewable with huge potential for growth and suitability that need further development, might be the best option and more necessary in order to meet the 2025 national energy mix target.

Indonesia’s abundant geothermal potential is not questionable. Despite having a considerable amount of potential, its utilization, especially for electricity generation, is not quite optimal. By 2020, only 2,130.6 MW out of 28,617 MW has been properly utilized. Unlike wind and solar energy, geothermal energy is not an intermittent source of energy and it has very high capacity factors, thus it can be a reliable source of energy.

Geothermal energy utilization has very unique attributes, which can be viewed as a promising opportunity when it comes to massive development. In contrast to other renewable energy projects, geothermal power projects must include upstream activities to verify the resource and to determine the most favorable location for development. This upstream phase is very similar to the upstream process of an oil and gas field or that of a coal mine. Such a unique attribute may allow us to have a transferability of management know-how from the fossil fuel sector to the geothermal energy business. The knowledge transfer may be able to help us to reduce the hefty risk that can come during geothermal development, for instance, with the lesson from the oil and gas sector, the declining phase of production might be recognized earlier, giving us the time to work on the operational and managerial solution to avoid the pitfall. The nature of the geothermal operation and the availability of knowledge transfer can reflect on the managerial maturity that the geothermal sector can offer, compared to the rest of the renewable energy sources, thus becoming its greatest opportunity. It is also implied that geothermal energy, far from being a simple market competitor, is internalized within the oil and gas industry as the inevitable way forward, hence the emphasis on the transferability of knowledge.

The geothermal energy sector has a fair share of obstacles when it comes to its development. Similar to the other renewables, the hefty cost has been one of the biggest obstacles that Indonesia has faced in the development of geothermal energy. The exploration and resource commercialisations are both costly processes, which makes them very reliant on heavy investments. Regulations have also become one of the major challenges for the geothermal sector, for instance, the land dispute caused by wavering regulations is most likely to hinder its development. There might have been many more underlying issues with regard to geothermal energy development, therefore a further investigation of the geothermal supply chain trajectory is necessary to address the potential barriers to its development. Furthermore, developing a set of policies also can be done to bridge these potential barriers and ultimately enhance the pace and magnitude of geothermal energy development (Halldorsson and Svanberg 2013). Despite the obstacles, just as much as the other types of renewable energy, the high potential, reliability, and opportunity that geothermal energy can offer, make it the most suitable renewable energy source to develop.

6.6. Conclusions

The FGD has provided unique inputs to this research via a combination of subjective and institutional leanings and experiences, particularly in identifying key enablers and barriers to renewable energy development. Throughout the course of FGD, the barriers were actually expected as there is an evident contradiction between policy and business, particularly in the planning and implementation stages. However, this does not necessarily mean that both stages do not adhere to the same vision. In particular, the private sector highlighted the lack of representative regulations truly needed to boost private participation in renewable energy development. The key enablers include constructing the national target as a framework and renewable development plans, building a forward-thinking scheme of supply chain management of renewable development, and regulation and policy refinement.

Regarding the renewable energy selection, geothermal energy has been considered the most suitable and feasible renewable energy source to focus on further development in Indonesia. Not only does it have a considerable amount of potential for generating electricity, but it also has the most unique characteristics out of all the other options of renewable energy. The FGD has identified that the geothermal energy projects must include a set of supply chain trajectories, which include the upstream, midstream, and downstream. The upstream phase in this supply chain trajectory is in fact similar to that of the oil and gas sector. This allows us to perform the transferability of management know-how from the fossil fuel sector. The lessons learned from the oil and gas sector should later be transferred over for the future development of geothermal energy, so as not to fall into the same pitfalls that impede and create inefficiency in the oil and gas sector. This implies a growing sense of corporate and institutional responsibility within the oil and gas sector, one that is visionary and should be capitalized on. Despite the tensions and disagreements between stakeholders, all parties agreed that the development of renewable energy, particularly geothermal energy should continue to be supported for the good of the public as well as the market. To do this, further investigation on geothermal supply chain trajectories needs to be done to identify the potential barriers and to design a set of policies that can bridge these barriers, thus enhancing the pace and magnitude of renewable energy development, or more specifically, geothermal energy.

Aside from directly absorbing the bold aspirations of each stakeholder, ‘reading between the spoken lines’ has provided plenty of room for abstraction and further inquiry. Most importantly, the FGD has succeeded in answering the three research questions posed at the beginning of this paper, we have acquired both (1) stakeholders’ recount and outlook of institutional and market challenges associated with renewable energy development in Indonesia, as well as their (2) responses for overcoming the challenges, (3) their collective views on the most feasible renewable energy to develop in the near future, and lastly, (4) the propositions to support the development of that particular renewable energy, i.e. geothermal, in Indonesia.

Chapter 7: Paper 4 - Unearthing the Dynamics of Indonesia’s Geothermal Energy Development

Paper accepted 6th July 2022 and published in Energies: Yudha, S.W., Tjahjono B., Longhurst, P., (2022) Unearthing the Dynamics of Indonesia’s Geothermal Energy Development, Energies 2022, 15, 5009; https://doi.org/10.3390/en15145009

Abstract

Indonesia has one of the world’s biggest geothermal energy reserves, accounting for 28.61 Gigawatts of electric energy (GWe). However, as of 2022, the installed geothermal capacity in Indonesia was only around 2.175 GWe, just 7.6% of its estimated potential. Geothermal energy development is required for Indonesia to empower sustainable energy systems and achieve its target of reaching 7.2 GW of geothermal energy by 2025. The geothermal energy sector is viewed as a complex dynamic system, with complicated challenges, including technical, financial, infrastructure, and many other issues. The purpose of this paper is to understand the complex nature of geothermal systems in Indonesia. To that end, this paper examines the geothermal development from a systematic and holistic standpoint, employing the interview technique to enable the conceptualization of the geothermal systems using the system dynamics (SD) approach. The SD model exhibits several underlying and important factors influencing the development of geothermal energy in Indonesia, such as capital investment, the collection of upstream data to reduce risk, infrastructure construction, pricing, incentives, permit procedures, environmental concerns, and public acceptance.

Keywords: geothermal; Indonesia; interview; system dynamics

7.1. Introduction

Geothermal energy is one of the types of renewable energy sources produced from the Earth's subsurface, which can be conveyed as hot water, hot steam, or a combination of both. Geothermal has become one of the most vital sources of energy with substantial growth potential in recent years (Barbier, 2002; Huenges and Ledru, 2011). Not only does it supply alternative energy to fulfill the energy demand aside from conventional fossil energy, but geothermal energy also contributes to reducing reliance on fossil fuels. As one of the clean energy sources, geothermal energy serves to mitigate the effects of global warming and health hazards associated with air pollution due to the usage of fossil energy sources, such as respiratory-related diseases (Fridleifsson *et al.,* 2008). Depending on the quality, geothermal energy can be utilized for district heating or harnessed to provide sustainable electricity (Fridleifsson., 2001). Lower enthalpy geothermal energy is frequently useful for direct usage (for example, room heating, tourism, agriculture, agroindustry, and fisheries) (Chu *et al,* 2021; van Nguyen *et al.,* 2015; Popovski *et al.,* 2003). Meanwhile, geothermal energy with medium to high enthalpy can be utilized to generate electricity (Kabeyi, 2019), which is common in active tectonics locations (Nasruddin *et al.,* 2016).

Indonesia has a wide range of types of geothermal energy, from low to high enthalpy, that can be utilized for both district heating and generating electricity (Darma *et al.,* 2010). Located on the "ring of fire", which traverses around the Pacific Ocean's margins (Mogg, 2001) and is home to the world's most active volcanoes and earthquakes (Pambudi, 2018), Indonesia has one of the world's largest geothermal energy reserves that can potentially be used to generate 28.61 Gigawatt-electric (GWe) (Hamilton, 1979; Darma, 2016). Despite the potential, Indonesia’s utilization of geothermal energy, particularly for electricity generation, is not yet up to par (Fan and Nam, 2018). As of 2021, geothermal energy used to generate electricity in Indonesia is at a capacity of 2.175 GWe or only 7.6% of its potential according to Indonesia's owned electricity company business plan 2021. In addition to that, according to Indonesia's National Energy Plan (RUEN), Indonesia pledges to achieve 7.2 Gigawatt (GW) of geothermal energy utilization by 2025, to increase its contribution to the energy transition toward net-zero emission in 2060 (Widyaningsih, 2017). However, the geothermal energy development in Indonesia is currently hampered by numerous hindrances, such as technical and regulatory issues, which have slowed down the progress of the geothermal sector quite significantly (Yanti *et al.,* 2021; Winters and Cawvey, 2015)

The development of geothermal energy is a very dynamic and complicated system that involves stakeholders, policies or regulations, institutions, technologies, and other interconnected and changing elements (Yudha and Tjahjono, 2019; Yudha *et al.,* 2021). Such complexity increases the challenge for the government to achieve the goal. In order to understand the complex nature of geothermal energy development, systematic and holistic approaches are required. Understanding the relationships between the elements involved in the development of the geothermal energy sector is becoming increasingly important and necessary in developing long-term strategies to boost the development of the geothermal energy sector.

In order to gain a more holistic, dynamic, and comprehensive perspective, it is necessary to solicit and analyze some critical information directly from the stakeholders in the geothermal sectors in Indonesia. The aim of this paper is therefore to analyze Indonesia's complex geothermal development structure. In so doing, the following research questions were subsequently proposed to ensure the achievement of transparent, repeatable, and credible research outcomes.

RQ1. How can the barriers associated with geothermal energy development in Indonesia be understood from the perspective of geothermal stakeholders?

RQ2. What are the key elements within the dynamics of geothermal energy development in Indonesia and how do they interrelate one another?

Such information gathering was primarily accomplished through literary work and interviews with primary stakeholders of the geothermal energy sector in Indonesia, with the ultimate goal to identify the key elements of the geothermal system. These key elements (and their interrelationships) were then modeled into a conceptual framework using the System Dynamics (SD) modeling approach.

This paper offers key contributions to the body of knowledge by providing an integrated and holistic view of Indonesia's geothermal system and by taking into account some disparate elements (e.g., infrastructure, permits, incentives, and public acceptance) that to date have not been well discussed in the extant literature, yet are vitally important to the geothermal system development. As this research incorporates information from all major geothermal projects operated by major actors or commercially operating companies in Indonesia to date, the SD model that is developed may act as a reference model that represents the geothermal system in Indonesia.

This paper is structured as follows: Section 1 provides the background and research questions of the research. Section 2 lays out the theoretical foundation for this research by elaborating on the various research pertinent to this research, so the gaps in the existing literature can clearly be identified. Section 3 describes how the research was carried out, including data collection and analysis methods. Sections 4 and 5 discuss the findings and the analysis of their implications for the knowledge. Section 6 concludes this research paper by outlining a set of proposals for Indonesia's geothermal sector development.

7.2. Related work

Geothermal development is complex, as it is surrounded by a plethora of external factors that frequently create uncertainty and hinder its development. The project scale, interrelationship, regulation, context, permit, and project stages are some of the factors that have been contributing to the complex nature of geothermal development (Vidal, 2008). Due to the dynamic interactions of various elements within the energy system, including the geothermal energy sector, many researchers have attempted to identify and understand the complex elements of the energy sector. One of the many popular methods used by researchers to untangle this complexity is by using the SD modeling technique.

Leaver and Unsworth (2001), Lowry *et al.* (2012), and Axelsson (2013) have used SD to map the technical aspects of the geothermal system, using the dataset from a few specific geothermal fields. However, despite the detailed technical aspects being offered, their work lacked several important non-technical aspects, which are deemed insufficient to fully elucidate the complexity of geothermal systems. Subsequently, Alfrink (2001), Jiang *et al.* (2016), and Splitter *et al.* (2020) used SD to elaborate on other elements of geothermal systems beyond the technical aspects, including the financial and economic aspects. Aslani *et al.* (2014), Saavedra et al. (2018), and Splitter et al. (2021) improved the deficiencies of the previous work by complementing the aspects of the geothermal systems to include a more holistic view of renewable energy in different countries, also using SD. While the aspects of geothermal systems have been incorporated in the abovementioned models, unfortunately, the models become too broad, leaving out too many details and aspects that determine the geothermal system.

In the context of Indonesia, SD in the geothermal energy sector has been trialed by Aditya (2017) who developed a framework that integrates the technical and economic aspects of the geothermal system using the Mataloko Geothermal Power plant in Kupang, East Nusa Tenggara. Akin to this work is a study by Setiawan *et al.* (2020) that complements Aditya's work with a more holistic approach by covering more than the economic and technical aspects.

Previous work, therefore, clearly demonstrates the paucity of research on renewable energy system dynamics, including geothermal energy. First of all, extant work in geothermal dynamics is currently focused predominantly on the technical and economic aspects. In particular, the elaboration of the dynamic relationship of the key elements beyond the technical and economical viewpoints is lacking, and even if they exist, they are poorly discussed. Secondly, although there are a number of researchers who have also attempted to develop a more holistic coverage of more aspects of the geothermal system dynamics, there are gaps between the methodological pathway and the geothermal SD model itself. For instance, much of the previous work was based on the data originating from a single case of geothermal in a single area as their base model, which may not be representative of the overall picture, hence the robustness of the system dynamic model being developed.

Therefore, in this research, the methodological framework of the research will be provided to bridge the gaps in how the geothermal SD can be developed. This research will also use the data from vast sources of geothermal plants in Indonesia, which improve the robustness, reliability, and accuracy of the SD models of the Indonesian geothermal system.

7.3. Research Design

This research is focusing on developing a conceptual framework for Indonesia's geothermal energy system. The overall research design comprises two main stages. In Stage 1, the semi-structured, in-depth interview method was carried out, involving a large number of key stakeholders in geothermal energy in Indonesia, to identify the key elements that play critical roles in the geothermal energy sector. In Stage 2, using SD modeling, these key elements and their structural interrelations are mapped and modeled to provide a holistic understanding of geothermal development complexity in Indonesia, incorporating technical, economic, political, and social aspects.

7.3.1. Stage 1 – In-depth Interview

This research employs a qualitative approach based on face-to-face in-depth interviews as the primary data collection method. This method was chosen Due to its capability to allow the readers to probe the stakeholders of the Indonesian geothermal energy sector in a systematic manner (Glass, 1976) using open-ended questions while allowing the readers to follow up with other questions that may not necessarily be pre-determined. The qualitative method was deemed suitable as it allowed the data collection flexibility and its capability of obtaining direct feedback to explain the complex phenomena yet requires in-depth analysis (Glass, 1976). In the in-depth interview, though based on semi-structured interviews (Kvale, 1996; Gill *et al.*, 2008), the data were generated in the form of descriptive and explanatory (Miles and Huberman, 1994; Galanis, 2018).

7.3.1.1. Profiles of the case companies and interviewees

The face-to-face, in-depth interviews incorporated the researchers as the interviewers and several geothermal stakeholders as the interviewees. Each one of these stakeholders represents the seven biggest geothermal industry companies that are commercially operating in Indonesia. In addition to the companies as the representation of the industrial sector, interviews are also conducted which involve a State-owned electricity company, the National Research and Innovation Agency, and Indonesia Geothermal Association. These respondents were selected to gain information from non-industrial perspectives. In order to keep the confidentiality of each interviewee, the name of the companies will be stated as "Company-X", and the interviewees' identities will remain as their initials.

Company-1 is a subsidiary of a state-owned oil and gas company in Indonesia. This company has been engaged in the utilization of geothermal energy since 2007. Company-1 has one of the biggest contributors to national geothermal capacity growth. As of 2020, the company has 672 MW of existing assets and 220 MW of existing projects. Currently, the company manages 15 Geothermal Working Areas, with a total installed capacity of 1,877 MW, which consists of 672 MW from its own operations, and 1,205 MW from JOC (Joint Operation Contract). The geothermal working areas from its own operations are located in North Sumatra, South Sumatra, Lampung, West Java, and North Sulawesi.

Company-2 is a geothermal company in Indonesia that has been operating since 2007. The company has three subsidiaries that operate in three different areas of Indonesia. Subsidiary-1 is located in the South Solok Regency, West Sumatera Province, with the initial synchronization of the 80 MW (nett) geothermal power plant and the 150 kV electricity network owned by a state-owned national electricity company. Subsidiary-2 is located in the South Lampung Regency, Lampung Province. This subsidiary is particularly located at the southern end of Sumatera Island, particularly the eastern coast of Lampung Bay on the volcanic cone of Mount Rajabas, with the capacity of a 2 x 110 megawatt (MW) geothermal project. Subsidiary-3 is located in the Muara Enim, Lahat Regencies and Pagar Alam City, South Sumatera Province, with a capacity of 92.1 MW as of 2022.

Company-3 is developing the 110 MW Blawan Ijen Geothermal Power Plant in Bla-wan Ijen, East Java, Indonesia (Ijen Project). The company has signed PPA (Power Purchase Agreement) with a State-owned Power Company for a 30 years contract. Commercial Operation Date starts in 2021, with the capacity of 2 x 55-Megawatt (MW) power generation and an approximately 28 km transmission line to the nearest substation.

Company-4 is an Indonesian state-owned enterprise engaged in geothermal exploration and exploitation since 2002. Initially, the company was established as a form of a joint venture between State-owned oil and gas company and a State-owned electricity company to manage WKP Dieng and Patuha according to the assignment from the government. Currently, Company-4 operates the Dieng and Patuha Geothermal Working Ar-eas (WKP) with a capacity of 55 MW each. In addition, this company also received an assignment from the government to manage WKP Umbul Telomoyo and WKP Arjuno Welirang.

Company-5 is a geothermal company that has been commercially operated for the past few years. The company has built one of the biggest geothermal power plant projects in a single contract with a capacity of 3 x 110 MW. The geothermal project is located in Pahae Julu and Pahae Jae Districts, North Tapanuli Regency, North Sumatra Province. The first unit was commissioned commercially in March 2017. The second unit started operating in October 2017. In May 2018, the third unit was established and also started operating. The geothermal power plants of Company-5 are fueled by brine and steam from both production and injection facilities at Silangkitang and Namora-l-Langit reservoirs.

Company-6 is one of Indonesia's largest geothermal energy producers. Company-6 partners up with two state-owned companies to manage geothermal energy into electricity in West Java Province. In Pangalengan, Company-6 Geothermal Wayang Windu Limited operates a geothermal facility with a gross installed generation capacity of 227 MW. In Sukabumi, Company-6 manages one of the largest geothermal fields in the world, with a gross installed generation capacity of 197 MW and steam sales capacity of 180 MW. In Garut, Company-6, Limited has a gross installed generation capacity of 216 MW and steam sales capacity of 55 MW.

Company-7 is one of the biggest developing geothermal project companies in Indonesia. The company's project is situated in Mandailing Natal Regency, North Sumatera Province. Company-7 obtained the majority shares of the company in mid-2016. Since then, the geothermal project has completed drilling operations for 18 wells and it has confirmed 55 MW proven resources at least. The project is targeted to connect 45 MW of electricity produced to the grid of a State-owned electricity company by end of September 2019, and it has been achieved as of 2022.

Company-8 is a state-owned electricity company or enterprise that deals with all aspects of electricity in Indonesia. The company has a subsidiary that specifically deals with geothermal energy. This subsidiary was established on January 28 2009 to carry out the development of the geothermal aspect in Indonesia with a function as a security of supply and cost-efficiency. Since its establishment, the company subsidiary managed to develop several geothermal-related projects and programs in Indonesia to support the Government in increasing the availability of electricity for all Indonesian people, such as the Geothermal Working Area of Tulehu, Lahendong Power Plant, and Mataloko Power Plant. In addition, the company has eight Geothermal Work area projects that have been developed.

Company-9 is the National Research and Innovation Agency, a non-ministerial government agency that is under and responsible to the President of Indonesia through the minister in charge of government affairs in the field of research and technology. This institution was first formed in 2019 and is attached to the Ministry of Research and Technology (MRT). As of 2021, The agency was separated from the MRT and was independent, and directly responsible under the president. Currently, the institution is working on the development of equipment and technology required for geothermal projects. The objective was to develop and produce geothermal equipment so that it can be produced on an industrial scale.

Company-10 is the Indonesia Geothermal Association, a non-profit organization, which acts as a forum or medium of communication, consultation, and coordination in order to enhance the members' understanding, cooperation, capabilities, and responsibility for the role of geothermal energy development in Indonesia. The organization represents the geothermal sector and is a forum for professionals, developers, and implementers of the geothermal sector, non-political and has no political affiliation.

Table 8 provides information on the initials of the interviewees, their position within their organizations, and their responsibilities to their respective organizations.

Table 8. List of the case companies and interviewees

Case	Code	Type of company; Position of the Interviewee: job description
Company-1	Interviewee-1A	Geothermal company; Director: Making major corporate decisions and managing the company's overall resources and geothermal operations
	Interviewee-1B	Geothermal company; Director of Exploration and Development: Overseeing the company's geothermal operations and maximizing the company's geothermal operating performance.
	Interviewee-1C	Geothermal company; Corporate Secretary: Planning and implementing corporate governance within the Company.
Company-2	Interviewee-2	Geothermal company; Director: Making major corporate decisions and managing the company's overall resources and geothermal operations.
Company-3	Interviewee-3A	Geothermal company; Senior Vice President Geothermal: Overseeing geothermal operations and maximizing the company's geothermal operating performance.
	Interviewee-3B	Geothermal company; Senior Geologist: Overseeing geological operations and site investigations of the geothermal project area.
Company-4	Interviewee-4	Geothermal company; Director: Making major corporate decisions and managing the company's overall resources and geothermal operations
Company-5	Interviewee-5A	Geothermal company; Stakeholder Management: Managing geothermal stakeholder mapping and coordinating with other geothermal stakeholders.
	Interviewee-5B	Geothermal company; Chief Administration: Providing input for geothermal business and strategic planning for the company
	Interviewee-5C	Geothermal company; External Relation: Liaising the company with other geothermal stakeholders
Company-6	Interviewee-6A	Geothermal Company; Deputy Director of Operation: Overseeing geothermal operations in the project area.
	Interviewee-6B	Geothermal company; Director of Strategic and Planning: Overseeing the company's operations and processes to identify strategic initiatives that would drive the company to its long-term growth and development.
	Interviewee-6C	Geothermal company; General Asset Manager: Managing and monitoring geothermal energy's asset of the company
Company-7	Interviewee-7	Geothermal / Renewable Energy Company; Head of Environment: Managing stakeholder relation, sustainability and business development.
Company-8	Interviewee-8	State-owned electricity company; Executive Vice President of Strategic Planning: Assisting in overseeing the company's operations and processes to identify

		strategic initiatives that would drive the company to its long-term growth and development.
Company-9	Interviewee-9	A national research institution; Deputy for Research and Innovation Utilization: Overseeing, managing, and evaluating the research activities, products, and further developments.
Company-10	Interviewee-10	Non-profit organization; President: Overseeing setting policies and strategic direction for the organization, both for the near term and the foreseeable future.

7.3.1.2. Guiding questions

The semi-structured interviews were carefully designed, where the interviewer pre-pared several questions prior to the interviews to help guide the conversation between the interviewer and the interviewees in regard to the geothermal development in Indonesia. The semi-structured interview was chosen as it allowed the interviewer to probe the interviewees for more in-depth information. In this way the interviewer can follow up on some questions and the reasons behind the answers, allowing the interviewees to open up about sensitive issues. It may also provide qualitative data as a basis for comparison with previous and predicted data (Dearnley, 2005). The guided questions were formulated based on the most common issues found in the geothermal industries in Indonesia, and the interviewer deep-dived the issues based on, but not limited to, the questions (see Table 9).

Table 9. List of research questions

QUESTIONS
Risk is one of the most important keys in decision-making for developing a project. What are your views on the risks associated with geothermal projects?
The geothermal energy development would depend on location. How has the location of geothermal prospects affected geothermal development?
The economic value of geothermal projects, particularly in revenue generation, seems to depend on how the geothermal is valued in the pricing mechanism. How is the geothermal pricing mechanism in Indonesia?
Infrastructure is one of the most important aspects of geothermal energy development. What are your views on the state of geothermal infrastructure in Indonesia?
What are the other aspects of geothermal energy that need to be considered to enhance its development?

7.3.2. Stage 2 – System Dynamics modeling

Following the interview stage, SD modeling was chosen as the theoretical lens through which the data were analyzed. This systems-level method was chosen because it is capable of providing a befitting theoretical perspective for constructing informative decision insights into renewable energy development (Govindan and Al-Ansari, 2019). SD modeling is a technique to identify, comprehend, and analyze many different complex systems. The behavior of a system's complexity normally requires a holistic understanding, for which the complex nature of the smallest unit, element, or constituent can be sufficiently understood, so better policy recommendations can be designed and ultimately proposed to improve the system (Sterman, 2001; Vitanov *et al.,* 2007).

In system dynamics (SD), conceptualization is a primary step needed to provide an understanding of the system that is being observed or analyzed. The causal loop diagram (CLD) is a conspicuously useful tool for developing a conceptual SD model. CLD contributes to the development of the systems' dynamic hypothesis. CLD enables the comprehensive depictions of causal relationships between the elements that were included within the system's boundary. CLD depicts the interaction of system elements with their neigh-boring environments, for example, the problem owner, stakeholders, system goals and criteria, and policy instruments to improve the system. In this research, the information from the stakeholders' interviews is analyzed using this approach, which is very useful in understanding and mapping the important cause-and-effect interrelationships among the geothermal system's elements (Randers, 1980).

7.4. Findings

Indonesia's geothermal resources, accounting for over 40% of global potential (or 28,617 MW) can be used as a power plant where geothermal fluid produced through production wells will go through a separation and cleaning process before entering the turbine and being converted into electric power. Despite its huge potential, there are still many obstacles that hinder the optimal utilization of geothermal energy, from both the technical and non-technical aspects. In this section, these obstacles will be analyzed based on the interviews with the geothermal stakeholders.

7.4.1. High risk of geothermal exploration

One of the biggest obstacles in developing geothermal lies in the early stage of the geothermal upstream project, which is the exploration. At this stage, geothermal potential and economics are highly dependent on the interpretation of Geophysical, Geochemical, and Geological (3G) survey results. The results of this 3G survey can provide a glimpse of the geothermal system play, which includes reservoir, temperature, and pressure values of the geothermal location. However, these 3Gsurveys are not sufficient as it needs to be supported by other data. The only way to prove this interpretation is by doing the test drilling. 3G surveys and test drilling can bevery expensive, as confirmed by Interviewee 1A:

"…it is very expensive to start a geothermal project. I will give you an example, the cost estimate to carry out the exploration stage including drilling with only a total of 3 wells, which was around USD 34.1 million, that included the Geological, Geophysical, and Geochemical surveys, but it is necessary for the making sure the geothermal area that we are assessing is promising or not." – Interviewee 1A

While Interviewees 2 to 7 did not provide the cost estimate of this exploration, all of the interviewees who represent the geothermal companies agreed that this exploration phase required hefty cost.

The more risk of a geothermal project will potentially increase the capital cost due to project loss, as stated by Interviewee 4:

"…the significant upfront cost of these exploration activities does not guarantee a significant return because if it turns out that after drilling there is no reservoir as

interpreted in the initial 3G survey, then the large costs paid by the geothermal developer, which is certainly very detrimental to the company, would fall through." – Interviewee 4

Interviewees 1 to 7 and 10 stated that the high risk of geothermal exploration as well as the expensive initial costs that must be faced by geothermal developers to carry out the exploration stage has made the development of geothermal energy becomes sluggish. Therefore, according to Interviewee 5A, government intervention in the upstream data strategy is needed:

"… upstream data strategy, including data integration from all state-owned companies, or government-funded drilling would be one of the scenarios that not only can make sure the potential of a geothermal area and increase the certainty during the exploration but also increase the geothermal attractiveness." – Interviewee 5A

Interviewees 1 to 7 concurred that a clear risk of geothermal exploration enables the bankability of a geothermal project and could ease the geothermal investment. Interviewee 3A, for instance, argued that:

"…a crystal-clear image of geothermal exploration risk is necessary for the bank to determine whether our project is bankable or not. Lower risk for them would make the process easier and more attractive." – Interviewee 3A

7.4.2. Geothermal locations within national parks or protected forests

Most potential geothermal drilling sites in Indonesia are located within protected forest areas, which has caused various problems for decades, as Interviewee 4 expressed:

"…around 80% of the potential sites are in protected forest areas where open-pit mining is prohibited by Forestry Law No.39/2004. This law is believed to have become a major barrier to the development of geothermal exploration in Indonesia, particularly during the permit approval." – Interviewee 4

For decades, geothermal activities had been classified as mining activities, which further created problems because, in conservation forest areas, it is completely forbidden to carry out geothermal activities so efforts are needed to determine the types of geothermal activities. Since geothermal activities are aimed at thermal extraction and not materials, therefore, it can be distinguished from mining activities such as coal or mineral resources.

The Indonesian government has issued Law No. 14 of 2014 which no longer includes geothermal activities as mining activities to allow geothermal exploration and production activities in protected forest areas. However, the regulation still has some loopholes that have not made it possible to fully carry out exploration and exploitation of geothermal resources within the national park. In addition to that, the situation of land disputes is often complicated by public resistance toward geothermal projects. Interviewees 1A, 3A, 4, 5A, and 6A agreed that carrying out drilling activities, building infrastructure, and placing geothermal power plant units, require the easement of land permits, otherwise, a geothermal developer will not be able to develop a geothermal working area. As Interviewee 3A mentioned:

"…if we want to increase the pace, make the permit process easier, because otherwise, many geothermal working areas in Indonesia, especially those currently undergoing the exploration stage, the geothermal utilization target of 7.2 GW in 2025 set by the government would be very difficult to achieve." – Interviewee 3A.

7.4.3. Pricing mechanism

Geothermal resource development projects in Indonesia can be categorized as Public-Private partnerships (PPP) where the business relationship formed between private sector companies and government institutions aims to carry out projects to provide electricity. In Indonesia, geothermal developers can only sell the electricity produced to the State Electricity Company (PLN) as a single buyer or off-taker. As a result, the existence of a market mechanism does not work and the government must periodically create tariffs to anticipate the dynamics of operating costs where the regulated tariff will be difficult to satisfy both the seller and buyer.

Interviewees 1 to 7 and 10 mentioned that there are several problems in the electricity buying and selling scheme in geothermal energy development projects in Indonesia. The State Electricity Company (PLN) the only electricity company in Indonesia does not directly approve the tender price. As Interviewee 1A stated:

"…we, as developers, have to negotiate with PLN to determine the price of the Power Purchase Agreement (PPA) after winning the tender where in most cases, the PPA price, roughly around 7 cents per kWh, is lower than the tender price." – Interviewee 1A

Interviewee 4 stated that this certainly has the potential to hamper the pace of investment in geothermal projects because investors find it difficult to determine the economics of the project, one of which is determined by the sale and purchase price of electricity.

Another set of problems also occurs during the bidding system as a result of this pricing mechanism. Interviewees 5A and 7 stated that the geothermal developers have difficulty determining a reasonable bid price, while the government also has difficulty finding serious developers. With the lowest bidder system being the winner of the geothermal prospect area license offered, some developers would try to propose very low and often unreasonable prices. Problems arise when the developer, after winning the license, did not kickstart the geothermal development project has been obtained because they feel that the price offered is not economically attractive.

Interviewee 6A stated that pricing regulation and incentive regulation areneeded to increase geothermal attractiveness:

"…in business, the more revenue we gained, the more attractive the business is, that's why we need the pricing mechanism that can attract the appetite for geothermal. Apart from that, incentives can be an appealing approach to attract the geothermal investors." – Interviewee 6A

7.4.4. Underdeveloped infrastructure affecting geothermal development

The problem of geothermal development in Indonesia is also strongly influenced by infrastructure conditions such as road access, transportation modes, and high-voltage electricity transmission that will be used to supply electricity to be produced by geothermal power plants. Interviewee 2 stated that one of the main problems faced by Indonesia as an archipelagic country is inter-island connectivity which directly affects domestic shipping costs. Interviewee 2 also mentioned that Indonesia's low level of investment in physical infrastructures such as roads and bridges has contributed significantly to Indonesia's connectivity problems. Transportation problems, congestion, and poor road quality are among the worst business constraints.

Interviewee 1A stated that in geothermal development, Indonesia's geothermal pro-spect locations are generally located in mountainous forest areas which are far from main access roads, both provincial roads and district roads, making it difficult to mobilize drilling equipment. Interviewee 5A explained that the higher the logistics and equipment mobilization costs, the higher the cost of geothermal development projects which in turn can make the investment in this sector less attractive. Quoting from Interviewee 5A:

"…when we first started the geothermal project, we needed to build the infrastructure such as road access, for example, and that cost a lot and it was one of the main factors to consider that could make the project less attractive." - Interviewee 5A

As a part of the infrastructure, the facility is also an important factor. Effective and efficient technology is also needed to reduce costs, especially during exploration. Interviewee 9 stated that Indonesia is capable of producing equipment for geothermal projects in the country, as currently the equipment test project is being carried out by National Research and Innovation Agency, at the Kamojang geothermal site.

7.4.5. Power-wheeling

Geothermal companies in Indonesia still have limited options to electrify their facilities and supply chains from geothermal energy sources. Therefore, it is necessary to consider a mechanism that can facilitate the transfer of electricity from geothermal energy sources to the company's operating facilities directly, or what is known as "power wheel-ing" or shared utilization of the electricity network. According to Interviewee 8, in Indonesia, the basic rules regarding power wheeling have been established through the Minister of Energy and Mineral Resources (MEMR) Regulation No. 1 of 2015 concerning Cooperation in the Provision of Electricity and Joint Utilization of the Electric Power Network.

First, the business model for this scheme is the transfer of electricity for the holders of the operating permit for distribution to the company itself. This makes it possible for companies that are able to build their own power plants even though they are far from company facilities. Another business model is buying and selling electricity between private power plants and holders of Business Permits for the Provision of Electric Power (IUPTL) in different Business Areas. However, it is difficult for the private sector to obtain a Business Area because most of the Business Area is owned by PLN (in one area, only one Business Area is allowed).

Interviewee 10 stated that the limitations of this business model can have an impact on the less massive transfer of geothermal energy to electrify private facilities.

Whereas the flexibility for the private sector to conduct direct transactions in this scheme can increase the development of geothermal energy on a large scale, when the private sector can help ensure electricity supply from geothermal energy sources and maintain electricity supply and tariffs. As mentioned by Interviewee 4:

"…to overcome this challenge, PLN needs to change the business paradigm so that the power wheeling scheme can be widely applied, starting from plant development planning, system operation, to target customers." – Interviewee 4

Interviewee 10 mentioned that many details of this scheme have not been regulated in the Energy and Mineral Resources Ministerial Regulation, including the portion of involvement of each party and technical instructions regarding network rental prices. As a first step to optimizing the available business model, PLN can start issuing technical instructions related to the formulation of transmission and distribution network rental prices as well as technical standard procedures for implementing joint utilization of the electricity network. On the other hand, the Ministry of Energy must also actively participate in ensuring transparency and fairness regarding network rental prices to provide certainty for both PLN and customers.

7.4.6. Public resistance

The factors that were least discussed but certainly not least important were related to the public acceptance of geothermal projects. Interviewee 6A stated that a lack of public understanding of the importance of geothermal projects often leads to resistance which eventually ends in the delay of geothermal development projects. This situation especially occurs when the geothermal project is still in the exploration stage where local governments, development companies, and local communities are still in the stage of recognizing each other and trust has not been built between each party. As stated by Interviewee 6A:

"…this is not news to geothermal developers, especially with the many reports in the mass media about the public's resistance to geothermal projects in Indonesia. However, in practice in the field often, companies have not carried out education or counseling sustainably and comprehensively." – Interviewee 6A

7.5. Discussion

This section discusses the development of the SD model that describes the relationships between elements that play a crucial role in the geothermal system development in Indonesia. The Causal Loop Diagram (CLD) is employed to link up the critical elements of the geothermal system that makes up the conceptual framework as shown in Figure 8. The loops and their elements were obtained from the interviews with the geothermal stakeholders (see Appendix 6A).

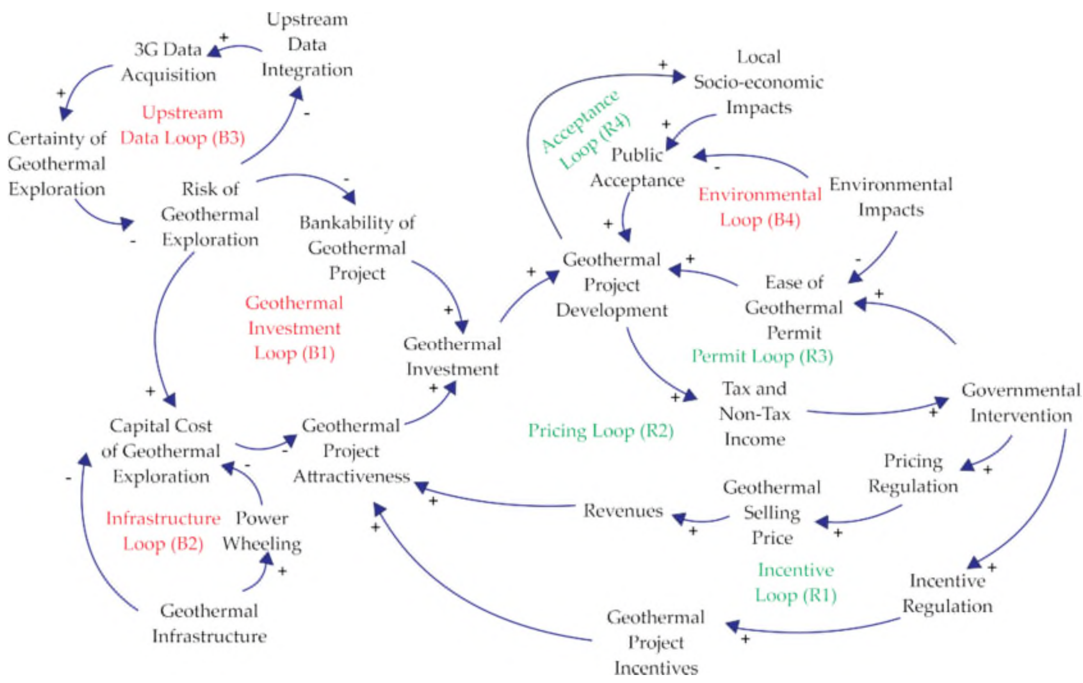

Figure 9. CLD of geothermal energy development in Indonesia

Table 10 lists the structure of the feedback loops within the conceptual framework. The loops detail multiple factors that can potentially enable and inhibit the growth of geothermal energy in Indonesia. Understanding these loops subsequently allows further investigations into the factors that can stabilize (or else strengthen) the regime so as to better align it with the goals of the geothermal systems being developed.

Table 10. Structure of the feedback loops of the conceptual framework

Loop	Type	Causal Effect Path
Geothermal Investment Loop (B1)	Balancing	Risk of Geothermal Exploration → Capital Cost of Geothermal Exploration → Geothermal Project Attractiveness → Geothermal Investment → Bankability of Geothermal Project → Risk of Geothermal Exploration
Infrastructure Loop (B2)	Balancing	Geothermal Infrastructure → Power Wheeling → Capital Cost of Geothermal Exploration → Geothermal Infrastructure
Upstream Data Loop (B3)	Balancing	Upstream Data Integration → 3G Data Acquisition → Certainty of Geothermal Exploration → Risk of Geothermal Exploration → Upstream Data Integration
Environmental Loop (B4)	Balancing	Environmental Impacts → Ease of Geothermal Permit → Geothermal Project Development → Public Acceptance → Environmental Impacts
Incentive Loop (R1)	Reinforcing	Governmental Intervention → Incentive Regulation → Geothermal Project Incentives → Geothermal Project Attractiveness → Geothermal Investment → Geothermal Project Development → Tax and Non-Tax Income → Governmental Intervention
Pricing Loop (R2)	Reinforcing	Governmental Intervention → Pricing Regulation → Geothermal Selling Price → Revenue → Geothermal Project Attractiveness → Geothermal Investment →

		Geothermal Project Development → Tax and Non-Tax Income → Governmental Intervention
Permit Loop (R3)	Reinforcing	Governmental Intervention → Ease of Geothermal Permit → Geothermal Project Development → Tax and Non-Tax Income → Governmental Intervention
Acceptance Loop (R4)	Reinforcing	Local Socio-Economic Impacts → Public Acceptance → Geothermal Project Development → Local Socio-Economic Impacts

7.5.1. Geothermal Investment Loop (B1)

Geothermal energy development is the primary focus of this research. The geothermal investment loop illustrates the way how geothermal investment in Indonesia and its elements are interconnected. This loop shows the balancing relationship between its dynamic elements. The lower risk of geothermal exploration will increase the bankability of geothermal projects which will eventually lead to an increase in investment in the geothermal project. More investment directed toward geothermal projects will increase the development of the geothermal project.

In addition to that, the lower risk of a geothermal project will reduce the capital cost of geothermal exploration, because when the geothermal risk is lower, its prospect is higher. Therefore, the risk of losing hefty costs for the exploration is also reduced and it decreases the overall capital cost that a geothermal project would require. The lower capital cost for a geothermal project will increase the attractiveness of the project and it can invite more geothermal investments.

7.5.2. Infrastructure Loop (B2)

The infrastructure loop shows how the infrastructure elements are involved within the geothermal project and the loop shows the balancing relationship between its elements.

The majority of the geothermal prospect areas in Indonesia are located in fairly remote, mountainous areas, which are often, far from the main access roads. Therefore, sometimes the developer had to build the road or other infrastructure once they decide to continue with the geothermal project development. However, this will also increase the capital cost of the geothermal project and subsequently reduce the attractiveness of the project. In addition to that, shared utilization of the electricity transmission or power wheeling can reduce the capital cost that includes building own transmission. With lower capital costs, it could potentially increase the attractiveness of the geothermal project.

7.5.3. Upstream Data Loop (B3)

The upstream data loop shows the balancing relationship between its elements and it mainly plays a role during the exploration stage as a part of the upstream activity. Upstream data integration, which includes government drilling and existing data from state-owned companies can be combined and integrated as part of the keys to increasing the certainty of geothermal projects.

Following the data integration, to complete the missing information, Geology, Geophysics and Geochemistry (3G) surveys, including the drilling test, are required to obtain the information and prospect of geothermal potential in an area during the exploration stage. The more and the better quality of the data, the more stability can be obtained and be used as a decision making for the continuity of the geothermal projects. The lower the risk of the geothermal projects will require further data integration with more detailed resolution and quality.

7.5.4. Environmental Loop (B4)

Environmental Loop shows a balancing relationship that consists of several integral elements. Despite geothermal being one of the renewables and eco-friendly energy sources, environmental concerns still exist, such as minor earthquakes, air and water pollution, thermal pollution, and land subsidence. However, these possible risks are manageable with the right mitigation plan and standardized technology. The more manageable risks regarding the impacts that a geothermal project has on the local environments, complemented by the right counselling, education, and communication, will increase the public acceptance of the geothermal project's development.

In addition, environmental risk assessment is one of the crucial parts of gaining the operational permit for a geothermal project. The better quality of the environmental risk assessment and mitigation will ease the process of obtaining the project permit.

7.5.5. Incentive Loop (R1)

Geothermal projects have a very high risk in terms of cost for their projects, which can be discouraging for geothermal investors and developers. As part of the financing aspect, incentives can be an appealing factor for the geothermal developer. Formulating an incentive scheme, which could be a fiscal incentive (e.g., tax holiday, exploration reimbursement), will make the geothermal projects in Indonesia more attractive and could invite more geothermal investments. As a result, more geothermal investments would result in more geothermal project developments that could generate both Tax and Non-Tax Income (such as profit from electricity sales through the State-owned electricity company) for the Government.

There are a few fiscal incentives that can be applied for the cases of geothermal development (Prihandito, 2021) , which include:

- Tax allowance: a reduced Income Tax for 6 years.
- Import duty facilitation: 2 years exemption from import duty for machinery and equipment, and also an additional 2 years exemption for raw materials for companies that use local machinery and equipment at least 30%.
- Tax holiday: tax easement provided for 5 to 20 years, with a maximum 100% reduction in income tax for a minimum investment of IDR 500 billion.
- Mini tax holiday: 5 years of tax relief, with a maximum income tax reduction of 50% for an investment of IDR 100-500 billion.

7.5.6. Pricing Loop (R2)

The pricing loop is one of the main keys to geothermal development. A suitable pricing mechanism or regulations that take into account the geothermal developers' input, such as Feed-in-Tariffs could result in a better geothermal selling price. A better selling price results in a revenue increase for the geothermal developers, which would make a geothermal project more attractive. Similar to the Incentive Loop (R1), increasing geothermal attractiveness could invite more geothermal investments, thus more geothermal project developments. Eventually, that could potentially generate both Tax and Non-Tax Income for the Government.

The situation where PLN, as the sole buyer or off-taker of electrical energy in Indonesia must be balanced with government intervention to implement regulations that can produce tariff schemes that are attractive to investors but still profitable for PLN. Further and more detailed studies on the most suitable method to reduce exploration and production costs should be carried out by the government, practitioners, and academics so that the baseline cost of a geothermal energy development project in Indonesia can be known.

7.5.7. Permit Loop (R3)

A geothermal system can vary depending on many aspects, such as geographical situation, politics, market, etc. The geothermal system in Indonesia is different from that in the Philippines (Ratio *et al.*, 2019), New Zealand (Kelly, 2011), Iceland (Ragnarsson, 2003), the United States (Tester *et al.*, 2021), and some other countries (Chamorro et al., 2012). In Indonesia, geothermal projects are often located in forest areas which can sometimes result in disputes and complicate the operational permit. Land-use permission procedures for infrastructure projects in Indonesia are still complex and have significantly hampered geothermal development in Indonesia. With a more reformed mechanism of the operating permit that is less complicated, it could be one of the factors that will increase the geothermal project's development. The easier these geothermal projects are executed, would result in more Tax and Non-Tax for the Government.

Land issue permit is a problem that cannot be ignored in developing geothermal energy in Indonesia. Therefore, multi-sectoral coordination and communication between ministries, local governments, and companies must be improved regarding this particular issue.

7.5.8. Acceptance Loop (R4)

Acceptance Loop depicts the importance of public acceptance from the local community for geothermal development. More resistance coming from the public would hinder and result in a delay in geothermal development.

Various methods of community approach must be studied and implemented, including the use of local community within the geothermal project environment, including during exploration, construction, and geothermal production activities to minimize the risk of rejection by the community around the project site. There have been many studies that offer various alternative approaches, one of which is the direct use of geothermal resources for tourism, drying of agricultural products, etc. which are expected to help develop the economy around the geothermal project area and involve the local community on an ongoing basis. In addition to that, incorporating the socio-economic factor that could benefit the local community, could also increase the public acceptance of the geothermal development project.

7.6. Conclusions

This paper illustrates the complex nature of geothermal development in Indonesia through model conceptualization by employing the SD modeling technique. The research employed semi-structured qualitative interviews of several important stakeholders of the geothermal energy sector in Indonesia. The information obtained was used as a basis for building the SD model.

The interviews highlight several aspects of the geothermal energy sector in Indonesia, including the high risk of geothermal exploration, restrictions for geothermal locations within national parks or protected forests, pricing mechanisms, underdeveloped infrastructure, power wheeling, and public resistance towards geothermal projects.

The SD diagram visualized the whole process, elements, and stakeholders that are incorporated within the geothermal system. The relationship between these elements is illustrated in the causal loop diagram forming four balancing loops, such as the geothermal investment loop, infrastructure loop, upstream data loop, and environmental loop, as well as four reinforcing loops, which include incentive loops, pricing loops, permit loop, and acceptance loop. These loops highlighted the behavior and the dynamics of the systems that influence the output of the system.

7.6.1. Theoretical contributions

This paper provides theoretical implications in several ways. Firstly, the geothermal business is a complex system with complex elements. There are a number of researchers that have identified the barriers to geothermal energy development, but most of the research has only been focusing on two major aspects, namely the technical and economic aspects. This paper provides a more holistic view and takes into account some other aspects or elements that are still poorly discussed but they are vital to geothermal development, such as infrastructure, permits, incentives, and public acceptance.

Secondly, this research complemented the work of Aditya (2017) and Setiawan *et al*. (2020), who identified the key elements of the geothermal SD models. This research addressed the shortcoming in their work, in particular the robustness of the models' references in representing the geothermal development in Indonesia. This research incorporates information from all major geothermal projects that exist in Indonesia to date, that are operated by major actors or commercially operating companies. Therefore, the framework may serve as a reference model that represents the comprehensive geothermal system in Indonesia.

Finally, this paper provides a novel way of identifying the complex elements of the geothermal energy businesses, by employing qualitative, semi-structured interviews, involving major stakeholders with diverse cases of a geothermal system. The information obtained from the interviews was used to develop the framework.

7.6.2. Practical implications

In terms of practical implications, the proposed framework can explain the causal structure and interconnections of every aspect of the geothermal energy sector, which is vital in enabling geothermal energy development. The proposed framework could be used to guide policy-level scenario planning by facilitating dynamic analyses of geothermal energy sectors.

A geothermal system can vary depending on many aspects, such as geographical situation, politics, market, etc. The proposed framework could be adopted by governmental institutions and organizations to advance decision-makers in the countries where geothermal energy can be developed. This is done by taking into account several key factors, such as geothermal potentials and settings, current policy, market condition, and stakeholders.

7.6.3. Limitations and future work

The future work will focus on formulating a quantitative SD model for geothermal development in Indonesia. Thus, it is envisaged to employ the model to explore several scenarios when proposing and implementing policies to accelerate and boost geothermal energy development.

Chapter 8: Paper 5 - Sustainable Transition from Fossil Fuel to Geothermal Energy: a Multi-Level Perspective Approach

Paper accepted 6th October 2022 and published in Energies: Yudha, S.W., Tjahjono B., Longhurst, P., (2022) Sustainable Transition from Fossil Fuel to Geothermal Energy: a Multi-Level Perspective Approach, Energies 2022, 15, 7435. https://doi.org/10.3390/en15197435

Abstract

Indonesia is currently undergoing the energy transition from heavily fossil fuel-dependent energy to cleaner sources of energy in order to achieve its net-zero emissions by 2060. In addition to reducing fossil fuel dependency, as one of the countries with the most geothermal reserves, the optimization of geothermal energy in Indonesia could be key to facilitating the energy transition. The objective of this paper is to elaborate on the transition process, which incorporates the destabilization of fossil fuel and the growth of geothermal energy, by analyzing the impact of both exogenous and endogenous factors on the supply chain structures of both sectors. This study employs workshop involving geothermal stakeholders in Indonesia, combined with the application of the Multi-Level Perspective (MLP) framework as the theoretical lens. The study found that energy demand, environmental awareness, energy regulations, energy supply chain, and geothermal potential breakthroughs are important aspects pertinent to the MLP components, namely the socio-technical landscape, socio-technicalregime and niche innovations. The socio-technical landscapes are exogenous factors that pressurize the energy sector regime allowing the niche innovation, in the form of geothermal innovation, to penetrate the fossil fuel regime, allowing it to transition to a geothermal regime.The transition pathways include several measures that could break down the fossil fuel and build up geothermal energy, through a number of schemes and incentives. Keywords: geothermal; Indonesia; interview; system dynamics

Keywords: energy transition; geothermal energy; multi-level perspective; supply chain; sustainability

8.1. Introduction

Energy is essential for economic development and human well-being, and it is inseparably linked to the challenges of sustainable development (Mundaca *et al*., 2018; Del Granado *et al*., 2018). With the growing concerns on climate change and energy security, the sustainable energy transition has attracted people all over the world. In the past decade, the history of significant movement of the energy transition has been traced, particularly in the European countries (Gales *et al.*, 2007; Allen, 2009; Kander *et al.* 2014), and the U.S. (Jones, 2014). Numerous empirical and conceptual studies have attempted to explain and advanced the understanding of how the energy transition can be performed and achieved. However, in actuality, the transition on a global scale is still underway and far from perfect (Del Granado *et al*., 2018; Jones, 2014) The key to energy transition heavily relies on the utilization of renewable energy, such as biomass energy, wind energy, solar energy, hydropower, and geothermal energy (Del Granado *et al*., 2018).

On a global scale, the utilization of renewable energy as the most vital key to energy transition would depend on the region's potential and suitability for the energy transition to take place. The study described in this paper focuses on energy transition in Indonesia; the world's fourth most populous nation, with over 270 million people living in a large archipelago of more than 6,000 inhabited islands (Hill et al., 2009). Based on the analysis carried out in previous work (Yudha *et al*, 2018; Yudha and Tjahjono, 2019), geothermal energy has been identified as the most suitable type of renewable energy to develop in Indonesia (Yudha et al, 2021). Indonesia is located on the "ring of fire," which traverses around the Pacific Ocean's margins and is home to the world's most active volcanoes and earthquakes (Hamilton, 1979; Manalu, 1988). According to research estimates, Indonesia possesses one of the world's largest geothermal energy potentials, accounting for approximately 28,617 MW (Nasruddin et al. 2016). These made it favorable for Indonesia to maximize the utilization of geothermal energy as a key to sustainable energy transition in Indonesia.

The energy transition is pushing the boundaries of energy modeling, not only in terms of new technologies, but also of frameworks capable of representing the interdependence between policymaking, expanding energy infrastructure, energy market behavior, environmental impacts, and supply security (Ediger, 2018). Particularly in geothermal energy, its development is linked to a complex system that includes stakeholders, institutions, regulations, technologies, and other interconnected and changing aspects (Chen et al., 2019). Understanding these aspects of the energy sector, including geothermal energy, its business processes, and supply chain would be the initial step in understanding the current situation of the energy sector in Indonesia. Therefore, the first research question proposed in this research is:

RQ1. What is the current state of energy business processes and supply chains in Indonesia from the perspective of geothermal stakeholders?

Following the dive into the energy business processes business, the research would also be focusing on how to facilitate and accelerate the journey of the energy transition. Answering this question would require analyzing some critical information directly from the stakeholders in the energy sector, particularly in the geothermal sector in Indonesia. Therefore, the purpose of this paper is to analyze Indonesia’s complex geothermal development structure from the perspective of the energy transition. The following research question was subsequently formulated to ensure the execution of transparent, repeatable, and credible research outcomes.

RQ2. What are the key factors that can facilitate the energy transition in Indonesia, which include the breakdown of fossil fuel energy and the buildup of geothermal energy, from the perspective of geothermal stakeholders?

Such information gathering was primarily accomplished through a workshop with geothermal energy stakeholders in Indonesia. The ultimate goal of this information gathering is to bring together previously fragmented information, experience, and decision-making processes related to the energy transition, such as the current state of fossil fuel and geothermal supply chain, as well as the key factors that can influence them.

This paper offers key contributions to the body of knowledge by providing insights on incorporating supply chain principles into the transition framework. In addition to that, this work demonstrates the implementation of the Multi-Level Perspective (MLP) theory on the sustainable transition, more specifically, in the context of the energy transition. This article also provides a novel way to analyze the key aspects of fossil fuel and geothermal by employing the qualitative workshop method, which involves major stakeholders with diverse cases of a geothermal system. The information provided by the stakeholders can be used as input to develop the MLP for the geothermal energy sector in the context of the energy transition. The obtained information and its analysis could be used to guide the policy-level scenario planning or policy recommendation in the energy transition context.

The paper is structured as follows. Section 2 lays out the theoretical foundation for this work by expanding on the various works that are relevant to this work, allowing the gaps in the existing literature that this work will address to be identified. Section 3 describes the research methodology, including data collection and analysis techniques. Sections 4 and 5 will go over the findings and how they relate to the corpus of knowledge. Section 6 concludes the paper by outlining a set of proposals for geothermal energy development that can accelerate the energy transition in Indonesia.

8.2. Multi-Level Perspective and its application to sustainability transition

The transition framework would require a breakdown of the old state and a buildup of a new state as a substitute for the old state. This transition process would normally occur as disruptive changes that develop gradually, as opposed to occurring in an abrupt or instant manner. To fully comprehend this phenomenon of a gradual change from the old to a new state, theoretical lenses are absolutely required.

Over the decades, numerous literature studies have emerged on the socio-technical transition (Van den Ende and Kemp, 1999; Geels, 2002; Geels, 2005; Geels, 2018), due to occurring serious societal issues, such as climate change, conventional energy resource depletion, urban eco-life and sustainability, biodiversity, etc. In recent years, there have been tendencies in, technology, science, and innovation studies to go further beyond the firm and the sectoral level to find structural solutions for these problems, with the perspective of socio-technical systems (Kern, 2018). Therefore, improved performance in multiple sectors requires socio-technical systems as the main focal analysis unit (Smith, 2005). Changes in such systems are based on mechanisms of societal and technological co-evolution (Smith, 2005).

Extant literature has investigated how a change in socio-technical systems occurs, which includes the patterns and dynamics that may lead to transitions, or in another word, structural transformation of these systems (Geels, 2010; Geels, 2005; Geels, 2018; Geels, 2010; Geels 2011 Geels, 2004). The MLP approach provides a framework for conceptualizing and analyzing complex transitions that occur through the developments on three system levels, namely niche level (micro-level), socio-technical regime (meso-level), and socio-technical landscape (macro-level), as well as their interactions within the system levels that can facilitate sustainability transition (Geels, 2002; Geels, 2004). MLP has been extensively cited as a framework that has been applied to comprehend a vast variety of socio-technical transitions, for example, studies of hydrogen and battery for electric vehicles (EV) (Van Bree, 2010), urban mobility or transport studies (Morani and Vagnoni, 2018), e-governance systems (Kompella, 2017), technological innovation (Markard and B. Truffer, 2008), and agriculture systems (El Bilali, 2019).

On the micro-level, the niche is a protective space where radical innovations are taking place (Smith and Raven, 2012). The niche acts as an incubation room from normal market forces, which allows research and learning through experience (Smith *et al.,* 2010; Smith, 2007). However, in order to develop the niches, it requires quite a bunch of factors, such as lead markets, the right space for early acceptance and experimentation, and as well as funding for research demonstration and learning (Smith *et al.,* 2010). The niche level can provide space and time for supporting networks to be established (Smith and Raven, 2012)

On the meso-level, or the socio-technical regime level, the rules that reproduce the various aspects of socio-technical systems are established (Papachristos, 2011). This level includes the 'rule-set or grammar' of processes, technologies, skills, corporate cultures, and artifacts that are embedded in institutions and infrastructures (Lawhon and Murphy, 2012). The socio-technical regime can cultivate incremental improvement along a trajectory, which eventually leads to regime shifts as the result of a cascade of changes over time thanks to the development created by niche and landscape (Van Bree, 2010; Berkhout *et al.,* 2004).

The macro-level, or socio-technical landscape includes a much wider context that in-fluences both the niche and socio-technical regime levels. The socio-technical landscape forms the external structure or context for the interactions of actors (Geels, 2018). Some examples of socio-technical landscapes are economic growth, wars, immigration, broad political coalitions, cultural norms, environmental problems, and paradigms (Van Bree, 2010; Berkhout *et al.,* 2004; Meadowcroft, 2011).

The literature has also identified a number of system-level interactions that support and influence existing transition pathways. In a landscape-niche-regime interaction, the regulatory framework and interrelationships with incumbent industries have commonly become barriers for niche actors in the socio-technical regime and landscape (Imbert *et al.,* 2019). In the landscape-regime interactions, the socio-technical landscape provides exogenous factors that can influence the regime and potentially destabilize an existing regime, as well as cultivate shifting toward improved regimes. In addition to that, changes that occur on the landscape level will be able to create pressure on the socio-technical regime (Geels and Schot, 2007). In niche-regime interactions, niche innovations gain internal momentum through several factors, such as learning processes, support from powerful groups, and price/performance improvements (Geels, 2011; Geels and Schot, 2007). In addition to that, the destabilization of the regime that took place during the transition can create windows of opportunity for niche innovations (Smith et al., 2010; Geels and Schot, 2007).

8.3. Methodology

This research is focusing on developing a conceptual framework to analyze the energy transition complexity that occurs through the development of different system levels, namely, niche innovation levels, the regime, and the landscape. In this regard, the overall research process includes two stages. In the first stage, qualitative data collection was employed in the form of a workshop, which includes several stakeholders in geothermal energy in Indonesia, to identify the key elements that play roles in the journey of Indonesia's energy transition, especially those regarding the geothermal energy sector. In the second stage, these key elements and their structural interrelations are mapped and modeled using MLP to provide a holistic understanding of the complexity of energy transition in Indonesia.

The workshop allows the researcher/interviewer to discuss a particular subject with a group of people (in this case the stakeholders in geothermal energy) who share their knowledge and experience (Glass, 1976). The workshop was also selected due to its benefits in the flexibility of qualitative data and the level of feedback capable of explaining complex phenomena and needs (Glass, 1976). The participants were provided with the opportunity to identify and analyze a certain topic and ultimately come up with a collective decision or consensus (Glass, 1976; Stanfield, 2013) and can generate data that can be both descriptive and explanatory (Miles and Huberman, 1994; Trevino *et al.*, 2020). This method is frequently used as a qualitative approach to gain an in-depth understanding of complex issues (Galanis, 2018; Ørngreen and Levinsen, 2017; Genus and Coles, 2008).

The workshop incorporated geothermal stakeholders in Indonesia as the participants. These participants represent the seven biggest geothermal industry companies that are commercially operating in Indonesia. In addition to these participants, the workshop also includes representatives from a state-owned electricity company, the National Research and Innovation Agency, and Indonesia Geothermal Association. These participants were selected to gain information from a non-industrial point of view. In order to keep the confidentiality of each participant, the name of the companies will be stated as “Company-X”, and the participants' identities will remain as their initials (Table 11).

8.4. Findings

In this section, several key issues on the stakeholder’s uptake of the energy transition are categorized (See Appendix 7A): (4.1) Increasing energy demand and depletion of conventional energy resources, (4.2) growing awareness of climate change and environmental impacts, (4.3) energy supply chain and business processes, (4.4) current policies and financing aspects, and (4.5) geothermal breakthrough potentials.

8.4.1. Increasing Energy Consumption and Depletion of Fossil Energy Resources

Indonesia's economy is still very dependent on fossil fuels, from the energy, industry, and transportation sectors. In the energy sector. Indonesia still mainly depends on coal and oil, in addition to gas and renewable energy. As Participant 5A explains, as of now, Indonesia has a total capacity of 70.96 Giga Watt (GW) of energy sources. Of the energy capacity, 35.36 percent of energy comes from coal, 19.36 percent came from natural gas, 34.38 percent from oil, and New and Renewable Energy from 10.9 percent.

Despite the fact that Indonesia's energy reserves are quantitatively abundant, Participants from Companies 2, 4, and 6 explained the scenario where the increase in energy consumption with no discovery of reserves for fossil fuels, could trigger an energy shortage and eventually lead to an energy crisis. Participant 6A argued that in actuality, Indonesia's domestic energy sources are still relatively abundant. Especially for the coal and natural gas sector. However, changes in consumption without further exploration would lead Indonesia closer to an energy crisis.

With the assumption that there are no further discoveries in terms of fossil energy reserves, the use of fossil energy sources will increase along with the increasing domestic consumption which would significantly decrease the remaining reserves. With this scenario, Indonesia's fossil energy reserves could run out in the next few decades. Participant-4 also stated that coal will run out in the next 65 years. Natural gas reserves are estimated to be 62.4 trillion cubic feet or only enough for 19.9 years. Meanwhile, for oil, the remaining reserves are only 43.6 trillion cubic feet, or equivalent to 9.5 years from now.

Participants from Companies 2, 4, 5, and 6 agreed that we can learn something from the energy crisis that is currently happening in several European countries. The energy crisis has provided a lesson for many countries, especially Indonesia to be able to maintain their energy security by reducing dependence on the fossil energy market, preparing carefully for the energy transition, and diversifying energy, especially renewable energy. As Participant 6A said:

"*The energy crisis that occurred as a result of the wars between Russia and Ukraine provided a lesson for Indonesia to accelerate the energy transition to renewable energy. Indonesia's abundant renewable energy reserves force Indonesia to move away from fossil energy. In addition, to prevent relying on only one energy source, Indonesia needs to diversify its energy supply and increase energy efficiency*." – Participant 6A

All participants expressed that the only way to move forward is reducing dependence on coal and gas, instead of increasing more fossil energy, by optimizing and utilizing more new and renewable energy resources as energy alternatives. In addition to that, all participants also agreed to put the energy demand as one of the vital reasons to move forward with the energy transition. According to Participant 9, Indonesia has a huge potential for optimizing renewable energy, particularly geothermal energy, which is currently underutilized. With the abundant potential of geothermal energy, Indonesia has a huge force and a key to do energy transition. Participant 9 also added that Indonesia has the NRE resource potential of more than 400 GW, of which only 2.5% or 10 GW has been utilized. Talking about geothermal alone, we have over 28 GW of potential, which could be the key to the energy transition. Now, the most important thing is to optimize the use of new and renewable energy.

8.4.2. Growing Awareness of Climate Change and Environmental Impacts

Climate change is a threat that is as catastrophic as the Covid-19 pandemic, if not worse. All participants expressed that the issue of climate change is a global and societal problem, and the impact of climate change is not bound to only certain areas. Therefore, this should be one of the main drivers of the energy transition for Indonesia, from high-carbon to low-carbon, or even zero-carbon. Participant 10 also added that every country must prepare and contribute because the issue of climate change is a global problem, there is no area limit to the impact of climate change. Indonesia, as a big country, needs to play an active role in the international community to carry out the transformation from high carbon to low carbon or even zero carbon emissions.

Table 11. List of the workshop participants and their brief company's profile

Case	Brief Company Profiles	Code	Type of company; Position of the Participant: job description
Company 1	The company has been commercially operating for a few years and it has built one of the largest geothermal power plant projects in a single contract with a capacity of 3 x 110 MW, which are located in three different areas of North Sumatra Province, Indonesia.	Participant 1A	Geothermal company; Stakeholder Management: Managing geothermal stakeholder mapping and coordinating with other geothermal stakeholders.
		Participant 1B	Geothermal company; Chief Administration: Providing input for geothermal business and strategic planning for the company
		Participant 1C	Geothermal company; External Relation: Liaising the company with other geothermal stakeholders
Company 2	The company has been operating since 2002 and it currently operates the Dieng and Patuha Geothermal Working Areas with a capacity of 55 MW each. Company 2 has recently operated in Umbul Telomoyo and Arjuno Welirang Geothermal Working Areas.	Participant 2	Geothermal company; Director: Making major corporate decisions and managing the company's overall resources and geothermal operations
Company 3	The company is one of Indonesia's largest geothermal energy producers. Company 3 manages some of the largest geothermal fields in Indonesia (Particularly in West Java): 227 MW in Pangalengan, 197 MW in Sukabumi, and 216 MW in Garut.	Participant 3A	Geothermal Company; Deputy Director of Operation: Overseeing geothermal operations in the project area.
		Participant 3B	Geothermal company; Director of Strategic and Planning: Overseeing the company's operations and processes to identify strategic initiatives that would drive the company to its long-term growth and development.
		Participant 3C	Geothermal company; General Asset Manager: Managing and monitoring geothermal energy's asset of the company
Company 4	The company has been operating in Indonesia since 2007. It has three subsidiaries that operate in three different areas: 80 MW in West Sumatra, 2 x 110 MW in Lampung, and 92.1 MW in South Sumatra.	Participant 4	Geothermal company; Director: Making major corporate decisions and managing the company's overall resources and geothermal operations
Company 5	A subsidiary of the state-owned oil and gas company in Indonesia. This company currently manages 15 Geothermal Working Areas, with a total installed capacity of 1,877 MW: with 672 MW from its	Participant 5A	Geothermal company; Director: Making major corporate decisions and managing the company's overall resources and geothermal operations

	own operations, and 1,205 MW from JOC (Joint Operation Contract. The company operates in several areas in Indonesia, such North Sumatra, South Sumatra, Lampung, West Java, and North Sulawesi.	Participant 5B	Geothermal company; Director of Exploration and Development: Overseeing the company’s geothermal operations and maximizing the company's geothermal operating performance.
		Participant 5C	Geothermal company; Corporate Secretary: Planning and implementing corporate governance within the Company.
Company 6	Currently operating the Ijen Geothermal Project in East Java with the capacity of 110 MW. As of 2021, it also operates additional 2 x 55 MW of geothermal project.	Participant 6A	Geothermal company; Senior Vice President Geothermal: Overseeing geothermal operations and maximizing the company’s geothermal operating performance.
		Participant 6B	Geothermal company; Senior Geologist: Overseeing geological operations and site investigations of the geothermal project area.
Company 7	One of the largest developers of geothermal projects in Indonesia. It has confirmed at least 55 MW of proven resource located in North Sumatra.	Participant 7	Geothermal / Renewable Energy Company; Head of Environment: Managing Stakeholder Relation, Sustainability and Business Development.
Company 8	A state-owned electricity company or enterprise that deals with all aspects of electricity in Indonesia. It has also developed several geothermal projects that take place in the Geothermal Working Area of Tulehu, Lahendong Power Plant, and Mataloko Power Plant.	Participant 8	State-owned electricity company; Executive Vice President of Strategic Planning: Assisting in overseeing the company’s operations and processes to identify strategic initiatives that would drive the company to its long-term growth and development.
Company 9	National Research and Innovation Agency. Currently, the institution is working on the development of equipment and technology required for geothermal projects.	Participant 9	A national research institution; Deputy for Research and Innovation Utilization: Overseeing, managing, and evaluating the research activities, products, and further developments.
Company 10	The Indonesia Geothermal Association. This is a non-profit organization representing the geothermal sector and is a forum for professionals, developers and implementers of the geothermal sector, non-political and has no political affiliation.	Participant 10	Non-profit organization; President: Overseeing setting policies and strategic direction for the organization, both for the near term and the foreseeable future.

During the Conference of Parties (COP) 21 in 2015, known as Paris Agreement, countries around the world committed to reducing carbon emissions by ratifying the agreement. According to Participant 3A, as one of the countries that participated in COP 21, Indonesia plans to reduce carbon reduce greenhouse gas emissions and be active in preventing climate change, which result in Indonesia ratifying Law No 16 / 2016 about the Ratification of the Paris Agreement to The United Nations FrameworkConvention On Climate Change. Participant 3A also stated that any measures that needto be taken to solve the climate change issue are important for moving forward and fulfilling the National Determined Contribution (NDC), including the transition energy,particularly in developing renewable energy sources like geothermal energy.

"*…as one of the countries participating in the Paris Agreement, we have ratified the Agreement and translated it to Law No 16 / 2016 and we pledged to reduce carbon emission by 29% with our effort or 41% with international aid, compared to business-as-usual scenarios of 834 Mt CO2e and 1,185 Mt CO2e, respectively, by 2030. Therefore, anything related to this mission should be the main priority, for example, optimization of geothermal energy for transition energy*." – Participant 3A

Participants 7, 9, and 10 mentioned that during COP 26 in Glasgow, the Government of Indonesia presented a new long-term strategy for a sustainable vision beyond Paris Agreement and updated the NDC, with a new set of goals, thus emphasizing the importance of energy transition and geothermal energy role in helping tackle the climate issue. As part of a pledge signed at the COP 26 climate summit, the goals are to reach peak national GHG emissions by decommissioning a quarter of its coal capacity in 2030, with a net sink in the forestry and land-use sectors, and to progress further towards net-zero emissions by 2060 or sooner. Participant 10 also added that Indonesia has committed to a coal power plant phase-out by 2040 and prioritized renewable energy. On top of that, Participant 10 also stated that the Government of Indonesia has also emphasized how geothermal can play an important role in reducing carbon emissions

In addition to this commitment during COP 26 to tackling climate issues by phasing out coal power plants, Participants from Companies 1 to 7 agreed that the process of Indonesia's energy transition will take some time and it will require other measures, such as slowly utilizing the remaining gas resources, while also enhancing the development of other's renewable energy sources until they are fully viable and can be utilized in a large economic scale and fully replace the conventional fossil energy sources. All participants have also agreed that the national commitments that the Government of Indonesia has made, should be translated as government interventions through policies or regulations.

Apart from looking at the bigger picture, in terms of how geothermal energy plays part in tackling climate change issues, Participant 5B stated that geothermal energy operation is one of the most environmentally friendly and has a relatively small minor environmental impact, which strengthens its position as a "Clean Energy". Participant 5B suggested that utilizing geothermal to its full potential, could be the main key to partially substituting fossil fuels such as coal.

8.4.3. Energy Transition Regulations and Schemes

According to Participant 2, there have been several regulations that have been the le-gal basis for the energy transition in Indonesia. These regulations are as follows:

- Law No 30 / 2007 about Energy
- Law No 30 / 2009 about Electricity
- Governmental Regulations 79 / 2014 about National Energy Policy
- Law No 16 / 2016 about Ratification of the Paris Agreement to The United Nations Framework Convention on Climate Change
- Presidential Regulation 22 / 2017 about National Energy Plan

In addition to these regulations, specific for geothermal energy, Participant 10 also added that Law No 21 / 2014 about Geothermal has been the legal basis specifically for the geothermal sector. The New and Renewable Energy (NRE) Bill, which is currently in the process of being passed in Parliament, would be the future legal basis for all types of renewable energy in Indonesia.

Apart from the existing legal basis, a number of future regulations would also be required to facilitate the shutting down of coal-based power plants. Participant 4 stated that removing fiscal incentives would be an initial measure that would discourage the coal producers. According to Participant 6B, the current domestic coal regulation, which is regulated by the Minister of Energy and Mineral Resources (MEMR) Decree 78 / 2019 about the domestic coal obligation, as well as the MEMR Decree 139/2021 about the domestic coal demand fulfillment and coal specification, are both very vital in shaping the coal industry. Participant 6A highlighted that the DMO scheme would force the coal producers to sell their coal for domestic needs at a cheaper price as opposed to selling it to the international market, which would be discouraging from the perspective of the producers. Participant 6B also added that the coal specification scheme would also limit the usage of coal for coal power plants as it only allows certain types of coal to be used for generating electricity. Therefore, this scheme would also be discouraging coal producers. In regards to the long-term plan, Participant 8 stated that the Government of Indonesia has planned to phase out the coal power plant by 2040.

In the geothermal sector, one of the main issues of geothermal energy that hinders its development and thus energy transition comes from the financing aspect. In Indonesia, the geothermal sector is categorized as Public-Private Partnership (PPP) where business partnership formed by private sector companies and government institutions aims to carry out electricity-generation projects. Geothermal developers in Indonesia can only sell their electricity to the State-owned Electricity Company (PLN) as an off-taker. As a consequence, this way, the market mechanism does not work and the Government of Indonesia must periodically create tariffs to anticipate the dynamics of operating costs where the regulated tariff will be difficult to satisfy both thedeveloper as the seller and PLN as the buyer. Therefore, the government needs to finda mechanism that can optimize the financing issues to attract investments or incentives,which could be fiscal incentives, such as tax holidays, tax allowance, import duty facilitation, etc. As well as non-fiscal incentives such as government-funded drilling and power wheeling schemes, so that geothermal energy can penetrate the existing energy market in Indonesia. As mentioned by Participant 10:

"…geothermal development requires large capital expenditures. So, both banks and investors will have to measure the return on their investments. As an off-taker, PLN requires affordable electricity prices, while geothermal developers are also looking for profitable prices, which results in the mismatch between the developers' expectations and PLN's. We hope that the government will provide an attractive financing scheme or government-funded drillings" – Participant 10

As a part of Indonesia's strong commitment to combatting climate change, the Government of Indonesia is planning to implement the Energy Transition Mechanism (ETM). According to Participant 2, the ETM consists of two schemes, namely the Carbon Reduction Facility (CRF), which is used to retire coal-fired power plants early in Indonesia, and the other one is Clean Energy Facility (CEF) scheme, which is aimed to develop or reinvest green energy facilities. Participant 2 also added that The CRF scheme allows the early retirement of coal power plants which includes compensation for the coal power plant developer or lender. The CEF scheme could be a way for coal producers to switch and reinvest in renewable energy-based power plants.

8.4.4. Energy Supply Chain and Business Processes

The energy supply chain is made up of a series of business processes that begin with the upstream source of energy and end with the consumer. In this section, the workshop participants provide insights on the energy supply chain and business processes of coal energy, as one of the major fossil energy sources, as well as geothermal energy as a type of renewable energy.

Participant 8 briefly describes the coal energy supply chain as a lengthy process that begins with upstream activities. The upstream process starts with preliminary surveys and coal exploration to find a potential coal source and reserve. Once these coal sources and reserves are identified, the land was cleared and the topsoil that covered the reserve was removed. The exploitation is done by performing coal blasting, drilling, and coal will be eventually collected through mining using heavy equipment. The coals are then processed through the crushing, sorting, and washing phase. Following the upstream activities, the mid-stream process continued by transporting the coal to a loading area or storage before the retails and is eventually consumed for a wide variety of purposes, such as powering the industry, transportation, etc. Participant 8 also emphasized that midstream processes in electricity generation continue by burning coal to produce steam. The steam is then used to power the turbine that generates electricity. Following electricity generation, the electricity is then transmitted, distributed, and eventually consumed by the end consumer.

The geothermal supply chain in Indonesia is unique, yet quite similar to that of the oil and gas industry. The early phase of the geothermal operation (upstream) consists of the exploration by a geothermal company. According to Participant 5A, at this stage, geothermal potential and economics are highly dependent on the preliminary survey of the potential area, test drilling, and the interpretation of Geophysical, Geochemical, and Geo-logical (3G) survey results. The results of this 3G survey can provide a glimpse of the geothermal system play, which includes a reservoir, temperature, and pressure values of the geothermal location. Participants from Companies 1, 2, 3, 4, and 6 stated that following the surveys and the tests, the assessed geothermal working area will undergo several bureaucratic processes. The assessed geothermal working area will be evaluated first by the government, specifically the Ministry of Energy and Mineral Resources (MEMR), before being designated or issued as an official geothermal working area. The issued geothermal working area goes through the tendering process and an operational permit will be issued for the winner. According to Participant 8, following the permit issuance, the Pre-Transaction Agreement (PTA) Signing can be optional between the geothermal company and the State-owned Electricity Company (PLN) as a sole buyer to discuss the price range of the geothermal products. According to Participant 1A, the company that has obtained the operational permit can conduct a feasibility study of the geothermal project, as well as the wells development and power plant construction in their working area. After the initial stage of the geothermal project, the company or the power producer is required to obtain the electricity supply business permit and undergo the Power Purchase Agreement (PPA) with the State-owned Electricity Company as the off-taker, to determine the price of steam or electricity that would be produced by the company. This step is one of the most vital processes as it will determine the economic value of the geothermal project. Participants from Companies 1 to 8 stated that when the PPA has been reached, the power producers can start setting up the geothermal project utilization, geothermal production to produce steam, processing them, and ultimately generating the electricity. Participant 8 mentioned that following the upstream processes, the electricity produced will undergo a midstream process, as they are transmitted and distributed through transmission facilities, and eventually end up in a downstream process as it was distributed to consumers (households, industry, etc.).

8.4.5. Geothermal Breakthrough Potentials

Enhancing geothermal development in Indonesia will require an assessment and consideration of some other aspects, such as the potential for innovation to break through the current geothermal energy regime to become more advanced, as well as how the geothermal can potentially invent new ecosystems or regimes.

Participant 10 expressed that technological advancement could be one of the keys to boosting the current pace of geothermal development. Participants 5A and Participant 9 confirmed that there has been recently a research project that involves both parties they are representing, in regards to geothermal project technology, where both parties are developing technology for small-scale geothermal systems. This way, the domestically manufactured technology could be implemented with less cost since they are not imported, and increase the geothermal energy development. Participant 9 stated:

"…*so far, geothermal technology that we used is imported and it could cost a lot and takes some time, this way. Right now, we start implementing the domestic-produced geothermal technology on a relatively small scale, which is 3 MW, to support the technological and geothermal development in Indonesia*." – Participant 9

Geothermal energy, as well as renewable energy, can potentially support and create new regimes. Participant 5A reported that one of the geothermal sites ofCompany 5 has been able to enhance local agricultural production. Utilizing geothermalsteam as part of the agricultural processes has helped the local farmers to boost their production. Participant 5A also highlighted that this has been one of the examples of the geothermal potential in terms of boosting the local economy and creating a new green ecosystem, and with further progress in its development, it can potentially create more ecosystems, such as electric vehicles (EV), green industry, clean cooking, and other ecosystems.

"…*geothermal energy has created multiplier effects, not only in terms of producing clean energy but also improving the local economy. In the future, it could create more ecosystems, like electric vehicles, green industry, clean cooking, and many other ecosystems*." – Participant 5A

8.5. Energy Transition from a Multi-Level Perspective (MLP)

Based on the findings, this section will discuss the energy transition from a Multi-Level Perspective (MLP), which consists of (5.1) elements of MLP (5.2) system-level interactions, and (5.3) transition pathways. Energy transition includes the breakdown of an old regime, or in this case, coal energy as the most dominating type of fossil fuel in Indonesia's energy sector, as well as the buildup of the potential new regime, which is geothermal energy. Figure 9 shows the MLP for coal energy as the old regime, while Figure 10 illustrates the MLP for geothermal energy as the new regime.

8.5.1. Elements of MLP

The MLP approach consists of three levels, namely the socio-technical landscape at the macro level, the socio-technical regime at the meso-level, and niche innovation at the micro level. In this section, the components of each level of the MLP for both old and new regimes will be discussed.

8.5.1.1. Socio-technical landscape

On the macro level, the socio-technical landscape consists of several landscape factors (the purple ellipses) that can provide pressure on the socio-technical regime as well as facilitate the energy transition. These landscape factors are interconnected with each other and they can result in "landscape products" that can act as key enablers to either break down the coal energy as an old regime or build up the geothermal energy sector as the new regime.

The breakdown of coal energy in Indonesia as a representative of the old regime stems from the ever-increasing environmental concerns about climate change issues. On an international scale, these concerns are what fueled the national commitments to combat climate change. During the latest COP 26 in Glasgow, the Government of Indonesia updated its Nationally Determined Contributions (NDC), with a new set of goals as part of a pledge signed at the COP 26 climate summit. As a part of the new goals, Indonesia plans to start by decommissioning a quarter of its coal capacity by 2030, in an effort to phase out its coal-fired power plants by the 2040s. Indonesia's commitments in the form of NDC are executed by the Government of Indonesia, as they intervene and change the course of the coal industry through several regulations. Through the incentive regulation, the Government of Indonesia could fiscally disincentivize coal-based energy. Domestic coal regulation regulates the coal specification scheme, which only allows only specific types of coal to be used for electricity generation. Therefore, this would help to minimize the massive coal production to only specific types. Domestic coal regulation also regulates the Domestic Market Obligation (DMO). As coal production depends on demands, which mostly come from international demands, the DMO scheme could potentially reduce the extensive production and import of coal as one of the energy sources. Lastly. The coal phase-out regulation is a long-term regulation that would be a vital legal basis for gradually shutting down the coal power plants in Indonesia for good.

Similar to the old regime, the buildup and the stabilization of geothermal energy as a representation of the new regime also stems from growing environmental concerns, in addition to the increasing energy demand. Environmental concerns are also the drivers of the formulation of national commitments. At COP 26, the Government of Indonesia presents the updated NDC, with a new set of goals, thus emphasizing the importance of energy transition and geothermal energy's role in helping tackle the climate issue. These national commitments are also translated into government intervention through several regulations. Prior to the utilization of geothermal energy, the geothermal developers are required to undergo several regulatory processes to obtain the operational permit and eventually obtain the Power Purchase Agreement (PPA). This PPA also includes the geothermal pricing agreement between the developers and the off-taker. As the pricing issue is still one of the main hurdles in the geothermal industry, a government intervention, particularly in regulating the geothermal price to be more competitive, could make a significant improvement in stabilizing the geothermal regime. Lastly, government intervention could result in incentive regulation that oversees a number of incentives such as fiscal incentives and non-fiscal incentives (e.g., government-funded drillings and power wheeling schemes). The relationship between the government intervention and the incentive regulation as well as the pricing regulation can be explained by a causal loop diagram (CLD) (Yudha *et al*, 2022).

8.5.1.2.Socio-technical regime

On the meso-level, the socio-technical regime consists of a series of supply chain processes for both the old and the new regimes. These processes are classified into upstream (blue rectangle), midstream (green), and downstream (orange).

In the old regime, the supply chain of coal energy, which includes the upstream, midstream, and downstream, is in a stable state and requires a breakdown in order for the energy transition to occur. The upstream process of coal energy starts from a preliminary survey and exploration to eventually finding the coal potential and reserve that is ready to be exploited. Following the initial processes, the next steps of the coal energy are land clearing and overburden removal, to exhume the coal reserves so that it is ready to be produced. When the coal reserves are exhumed, the coal production is executed involving coal drilling, coal blasting, and coal mining. After the coal production, the coals are processed, which includes crushing, sorting, and washing. The midstream processes of coal energy start from coal hauling or transporting from the mining site to a coal loading area. The loaded coal is then ready for retail and further, coal consumption. As a part of the downstream processes, coal consumption can be varying depends on what the customers need, for example, fueling industrial machines, fueling conventional coal-based vehicles, or generating electricity. Specific to electricity generation, the supply chain processes continue as midstream since itrequires further processes. In the case of electricity generation, the purchased coal is burned to produce hot steam that can power the turbine and ultimately generate electricity. The produced electricity is then transmitted and distributed for electricity consumption through the electricity network system. For the downstream process, the distributed electricity will be in retails and consumed by the end consumers, which could be residential, business, industrial, and public.

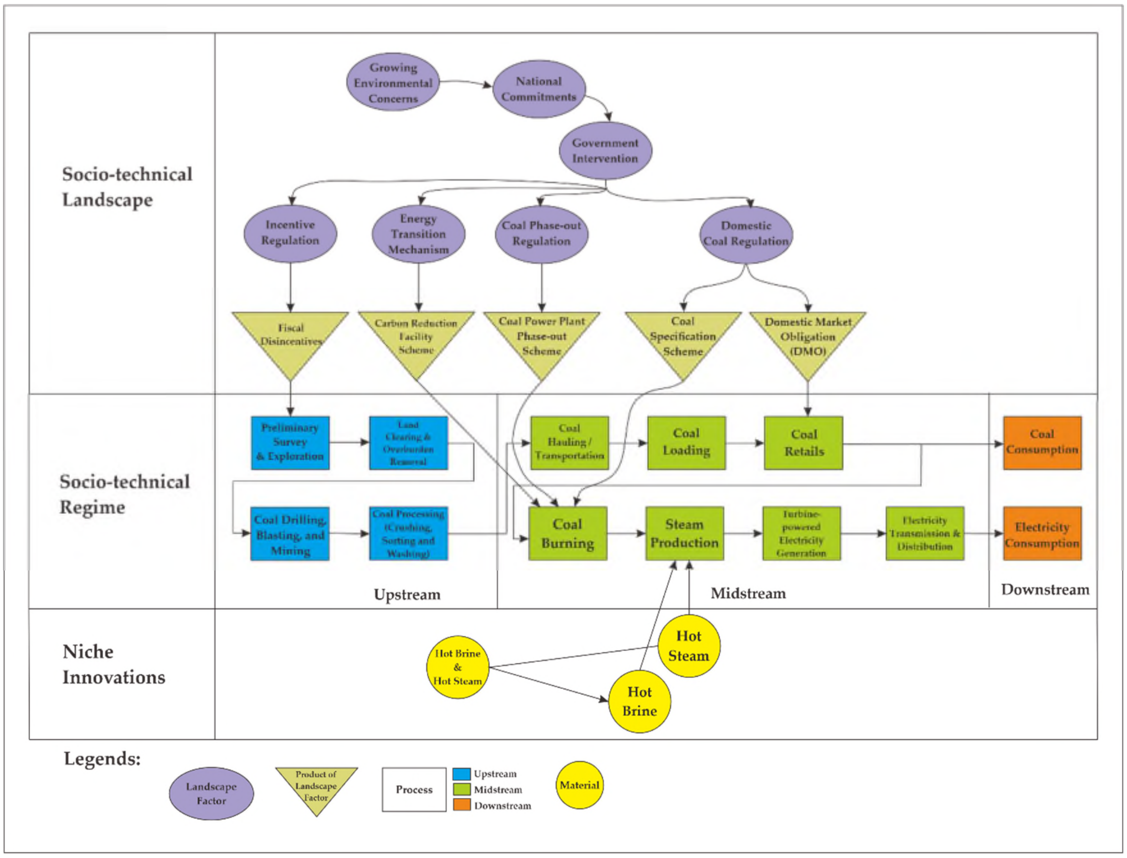

Figure 10. MLP diagram for coal energy as the old regime

Similar to the old regime, the new regime also includes the upstream, midstream, and downstream processes. In this supply chain flowchart, the geothermal upstream processes are defined as business processes that involve the exploration activities or searching out the geothermal prospect area, extraction of geothermal products, production, and processing of the products. The upstream processes are primarily executed by the geothermal developers. The initial phase of upstream activities includes a preliminary survey of the geothermal potential area, test drilling, and the Geophysical, Geochemical, and Geological (3G) survey results. Although this phase requires hefty cost and has a very high risk, it is one of the most important steps as it determines geothermal potential and its economic values. When these are determined, following the initial upstream activities, the geothermal developer has to undergo a series of necessary regulatory processes to eventually get the operational permit and purchase agreement. After the regulatory processes are dealt with, the developers are proceeded to perform pre-production processes, which include well development, power plant construction, and project utilization. This phase can also be very costly, as it involves the procurement of all necessary technology and equipment for setting up geothermal production. When the necessary steps have been taken, the production phase can be executed and results in geothermal products (hot steam hot brine, or both). These products will undergo some geothermal processing. The hot steam can be used directly to power the turbine which generates electricity as the final product. The hot brine can be used to heat up other secondary fluids that can turn into steam to power the turbine that generates electricity. If both the hot steam and hot brine are mixed up, the products go through the separator first and are then utilized differently to both powers the turbine and generate electricity as their final product. The midstream and downstream processes conclude the final processes of the geothermal supply chain. The midstream processes here are defined as the business processes in the geothermal business following the electricity generation. In Indonesia's case, these processes mainly involve the State-owned electricity company as the off-taker. In the midstream stage, the electricity generated by the developer is transported through transmission facilities, which are mainly owned by the off-taker. Similar to the old regime, after the transmission, the final product of electricity that is ready for retail will be eventually distributed to the end consumers through the electricity network system. For the downstream process, the distributed electricity will be in retails and consumed by the end consumers.

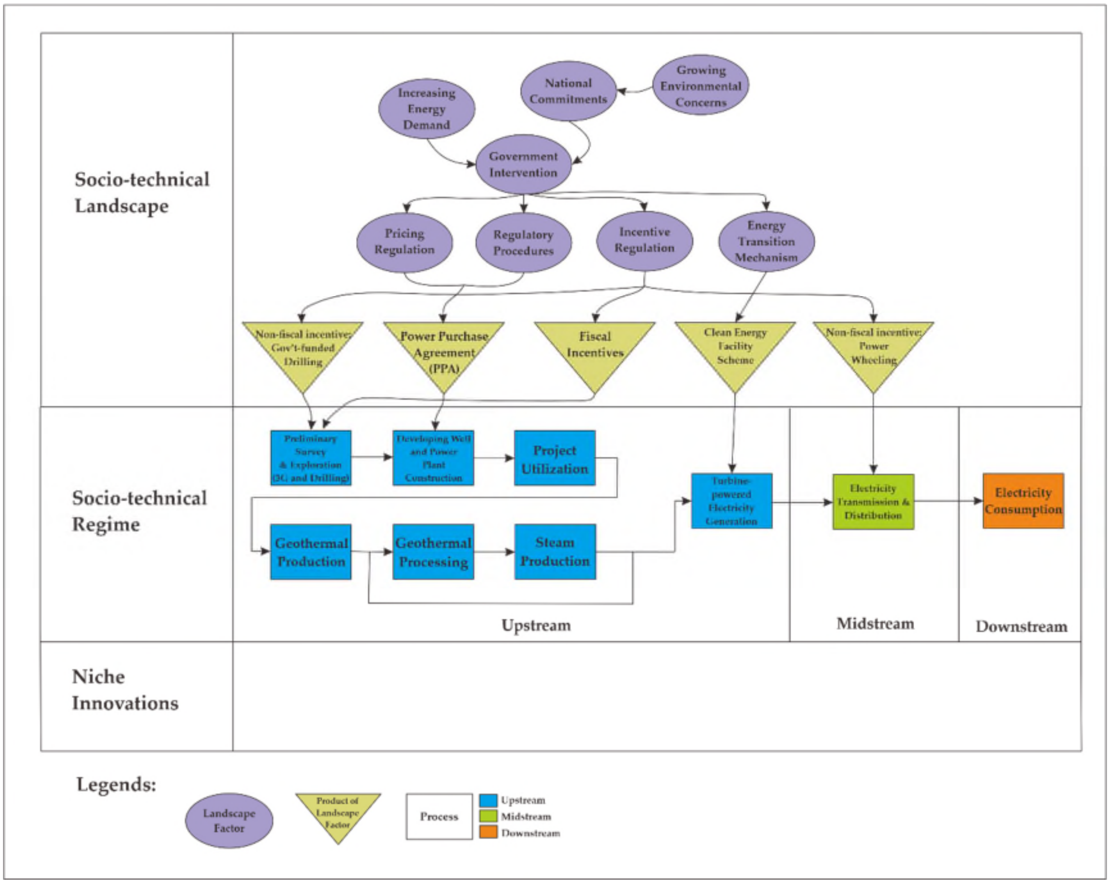

Figure 11. MLP diagram for geothermal energy as the new regime

8.5.1.3. Niche Innovations

At the micro level, niche innovations consist of material transformation (yellow circle) that can be identified and could potentially create an opportunity for transition. In this study, the material transformation includes the ones that could potentially break down the coal energy as the representation of the old regime and build up the geothermal as the representation of the new regime. The identified niche elements in this study are the hot brine and the hot steam for electricity generation.

8.5.2. System-Level Interactions

Following the identification of the elements for each level of the MLP for both the old regime and the new regime, the interactions between these different levels will be analyzed in this section.

8.5.2.1.Landscape-regime interaction

The socio-technical landscape consists of multiple factors that act as drivers and giving pressure on the current regime. In terms of the energy transition, the landscape factors can provide some key enablers as the landscape products and they are able to facilitate the energy transition by breaking down the coal energy in the old regime and stabilizing the geothermal energy in the new regime.

In the old regime, government intervention stems from the increasing awareness of environmental concerns that are translated into national commitments to combat climate change issues, particularly related to the energy sector. In order to destabilize coal energy, the government can intervene and shape the coal energy industry through several regulations, such as incentive regulation, domestic coal regulation, and coal phase-out regulation. Part of the reason why coal energy has been dominating the energy industry in Indonesia is due to its cheap price and the number of incentives that it receives. Reducing, limiting, or even removing the incentives for the coal industry would be some of the ways that can be executed to destabilize the coal regime. As of 2022, the Government of Indonesia planned to only incentivize the 'downstream coal', which includes coals that are processed and converted to some other 'downstream coal' products such as liquified and gasified coal, which emit less carbon than conventional coal. This way, the Government of Indonesia encourages the new way of utilizing coals in a 'cleaner' way as opposed to the conventional way and simultaneously reduces the further extensive coal exploration in the future. Domestic coal regulation provides regulations on coal specification and domestic market obligation (DMO). Coal specification will only allow specific types of coal to be used for coal power plants to generate electricity. Therefore, this will sort out and reduce the burning of other types of coal that are not qualified for electricity generation, which would also discourage coal production. Domestic Market Obligation (DMO) requires the coal producers to sell their coals for domestic use in Indonesia, where the price is lower than the international coal market price. This scheme impacts coal retails and discourages the overall mining business. In addition to that, the Government of Indonesia also plans to start by decommissioning a quarter of its coal capacity by 2030 in an effort to phase outcoal power plants completely by 2040, which would directly impact the electricity generation from burning coal to some other measures. Lastly, the coal power plant phase-out can be accelerated through a new measure called Energy Transition Mechanism (ETM). One of the schemes from this ETM is called the Carbon Reduction Facility scheme, which allows the coal power plants to be shut down prematurely and this scheme will be able to terminate these power plants so much earlier than their initial operational contract. As compensation for the premature termination, the coal power plant developers are able to get compensation money from the Government of

Indonesia, where the amount would depend on their remaining operational time in the initial operational plan and contract.

Similar to the old regime, government intervention also stems from the ever-increasing environmental concerns in addition to the increasing energy demands, which are translated to national contributions and ultimately adopted as government intervention. In order to solidify geothermal energy as the new regime, the Government of Indonesia's intervention can be performed through multiple factors, such as geothermal regulatory procedures, pricing regulation, and most importantly incentive regulation. Part of the reasons why geothermal energy development has been hindered is due to the geothermal electricity price that is not sufficiently competitive compared to the fossil-based electricity price, especially from the coal power plant. Therefore, making the geothermal price competitive through the pricing regulation would boost geothermal development. The competitive pricing of geothermal electricity would be part of the Power Purchase Agreement (PPA) after geothermal developers fulfilled the regulatory procedures. The PPA, along with the operational permit, is one of the most important factors to obtain for the developers prior to the pre-production process, such as well development and power plant construction. Stabilizing geothermal development would also require incentives, which include fiscal and non-fiscal incentives. Fiscal incentives would certainly be increasing the attractiveness of geothermal projects to potential investors and geothermal developers, these fiscal incentives could be in the form of tax allowance, import duty facilitation, tax holiday, etc. The fiscal incentives could stimulate the overall geothermal industry and production. In addition to fiscal incentives, non-fiscal incentives would also stabilize and boost geothermal development in Indonesia. As the exploration phase of geothermal is high risk and requires a hefty cost, government-funded drilling projects could be helping the geothermal projects, particularly in the exploration stage. In addition to that, the geothermal developers in Indonesia still have pretty limited options to electrify. Therefore, having a scheme for sharing the utilization of the electricity network through power-wheeling for electricity transmission and distribution. Lastly, another type of scheme from the ETM is called Clean Energy Facility scheme, which would boost renewable energy power plants, including geothermal energy. In this scheme, the developers of the coal power plants prematurely terminated as a result of the Carbon Reduction Facility scheme would also be incentivized in the form of a wide range of operational aids if they choose to develop and switch to renewable energy power plants.

8.5.2.2. Regime-niche interaction

The socio-technical regime of the geothermal energy sector consists of a series of important supply chain processes for both the old and new regimes. The niche level exhibits radical innovations that could either potentially boost the transition or fail to be implemented.

In the context of geothermal energy, the main aspect of the niche level is mainly related to the material transformation that occurs in the regime that could potentially break through the current processes in the old regime and provide a way for the new regime to take place in the process. When it comes to electricity generation, hot steam production was needed to power the turbine and produce the electricity. In the coal supply chain process, this hot steam production is mainly coming from coal burning, which would result in carbon emissions. In the geothermal supply chain process, this hot steam can be directly utilized as a part of geothermal products, or from additional processes involving heat exchange of the hot brine and other secondary liquid that is converted to hot steam. Both coal and geothermal energy require hot steam production to produce electricity. Therefore, replacing the steam production to produce electricity in the old regime with the one acquired from the geothermal production would be a window of opportunity for the transition.

8.5.2.3. Landscape-niche interaction

In the context of geothermal energy's role in the energy transition, the current aspects of the geothermal landscape appear to give more pressure on the regime, rather than the niche. While most of the aspects of the landscape focus on the destabilization of fossil fuel energy regimes and empowering other renewable energy, there does not seem to be a direct interaction between the landscape and the niche. As the niche could be also related to the advancement of technology, government regulation as a part of the socio-technical landscape could be one of the ways to encourage research and development, particularly in powering the turbine to power electricity by using any kind of process or energy source.

8.5.2.4. Transition Pathways

After analyzing both coal and geothermal energy as the representative of the old and the new socio-technical regime respectively, through different socio-technical levels as well as their interactions, this section will discuss the transition pathways towards the transition from the old regime to the new regime (Figure 12. Energy transitions are disruptive changes that develop gradually, as opposed to occurring in a shock-wise manner. In principle, the energy transition requires the destabilization of fossil energy regimes and the enhancement of renewable energy, including geothermal energy.

Figure 12 illustrates the graph of transition pathways of two energy sectors, namely coal energy in the old regime (red curve) and geothermal energy in the new regime (blue curve). The vertical y-axis shows the system state of each regime, while the horizontal x-axis represents the time in years. Each point on the curves represents the milestones that consists of key enablers for the energy transition to occur from the point of view of both the coal and geothermal sector. These key enablers originated from the landscape products that were developed from the landscape factors in the MLP for both old and new regimes.

The breaking down of the old regime started by implementing fiscal disincentives for the existing coal power plants. The implementation of the financial aspect is very vital in triggering the transition; therefore, any financial-related policies are applied earlier. As a part of the destabilization, applying domestic coal specifications for power plants potentially reduced the coal energy as only several specific types of coal can only be used to generate electricity from the power plant. In addition to that, extensive coal production is firmly related to high coal demand, especially coming from international demand. The implementation of the Domestic Market Obligation (DMO) scheme would force coal producers to sell their coals in order to fulfill domestic demand at a relatively lower price compared to international pricing. This scheme would discourage the coal producers and reduce the extensive coal production. The end goal of the coal energy breakdown would be the complete coal phase-out. The breakdown of coal has been included by the Government of Indonesia as a part of the national commitment during COP 26. To reach net-zero emission by 2060 or earlier, the Government of Indonesia plans to start by decommissioning a quarter of its coal capacity by 2030, in an effort to phase out its coal-fired power plants by the 2040s (Government of Indonesia, 2021; Ordonez, 2021),which results in the coal curve being plummeted down by 2040 (Fig 12, red line). In addition to this, the coal phase-out can also be done prematurely by implementing the Energy Transition Mechanism (ETM) through the carbon reduction facility scheme.

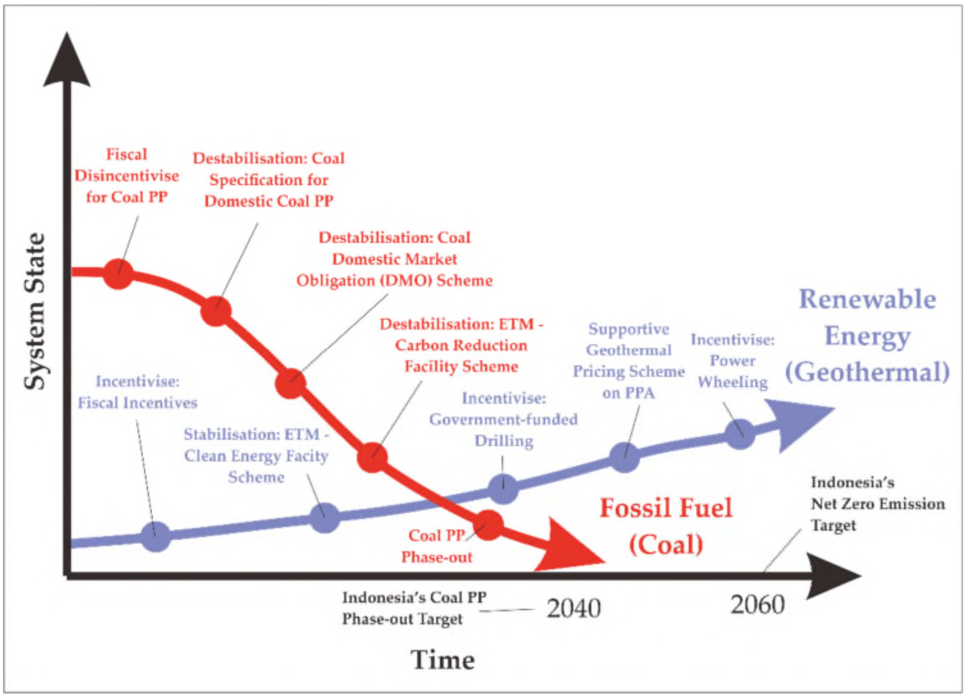

Figure 12. Illustrative graph of the transition pathways of the coal and geothermal energy sector over the years

Similar to the old regime, the buildup of the new regime also started by implementing fiscal incentives for the development of renewable energy, particularly geothermal energy, as the financial aspect is very vital in triggering the transition. Recently, the Government of Indonesia has taken regulatory steps to support the energy transition through Presidential Regulation 98/2021 on Carbon Economic Value, and Law No 7/2021 on Tax Regulation Harmonization, which covers the carbon tax (Putra *et al*, 2021). One of the initial measures to support geothermal energy is performed by stabilizing the sector, which can be done by implementing the clean energy facility scheme as a part of the ETM. Following the stabilization, geothermal energy would require other types of incentives to support geothermal development. One of the primary incentivization is government-funded drilling, which is firmly related to ease and provides support to the upstream geothermal processes. Following the incentive on the upstream-related process, the geothermal sector development necessitates a supportive geothermal selling price that is included in the Power Purchase Agreement (PPA). Lastly, the non-fiscal incentives, namely the power wheeling scheme, would be a vital aspect of sharing the electricity network in post-geothermal production.

8.6. Conclusions

This paper illustrates the complexity of energy transition that involves both the old regime and the new regime. The old regime is represented by coal energy, as a type of fossil fuel energy, while the new regime is represented by geothermal energy, as a type of renewable energy. Several important aspects or findings are identified, discussed, and used as input for the MLP. Energy demand, environmental awareness, energy regulations, the energy supply chain, and geothermal potential breakthroughs are among these factors. The MLP analysis is employed to identify the transition from the old to the new regime, along with its elements.

There are three main elements or levels of the MLP, namely the socio-technical landscape, socio-technical regime, and niche innovations. The socio-technical landscape consists of a number of factors that are interlinked with each other and these factors put pressure on the old regime to ultimately break it down and build up the new regime. These landscape factors are translated into "landscape products" that act as key enablers to be implemented and influence the regimes. In the old regime, the landscape factors stem from growing environmental concerns that are translated into national commitments executed through government intervention. This intervention results in a number of regulations that impact the current state of coal energy. Similar to the old regime, the new regime is also affected by the landscape factors that stem from growing environmental concerns that are translated into national commitments, in addition to the increasing energy demand. These factors also resulted in government intervention that is executed through several regulations that are meant to boost geothermal as the new regime. On the socio-technical regime, the current state of the supply chain for both the coal and geothermal regime are identified. The supply chain business processes in both regimes are classified into upstream, midstream, and downstream. To facilitate the energy transition, the landscape products will be applied to some of these processes. Lastly, niche innovations are associated with material transformation that provides an opportunity to break the processes in the old regime and use the new regime instead. In this research, the identified niche is associated with steam production to power the turbine to generate electricity. Steam production can be done by using the hot steam and/or transforming the hot brine to create secondary hot steam to power the turbine as opposed to burning coal.

Following the MLP analysis, this research also identifies Indonesia's energy transition pathways from the old regime, which is represented by coal energy as the current major source of energy in Indonesia, to the new regime, which is represented by geothermal energy. The breakdown of the old regime starts with disincentive, followed by destabilization, and ultimately the complete phasing out of the coal power plant in Indonesia by 2040. The buildup starts with fiscal incentives, followed by stabilization of a few aspects, and incentivize in non-fiscal aspects, in order to achieve Indonesia's Net Zero Goal in 2060.

8.6.1. Theoretical contributions

There are several theoretical contributions that this paper has been able to provide. This paper employs the supply chain principles and combines them with the transition framework. This work also illustrates how the energy supply chain model can be used to analyze and enable the energy transition. In addition to that, this work demonstrates the MLP implementation on the sustainable transition, more specifically, in the context of the energy transition, therefore providing the insights that MLP is not just a framework, but it can be implemented for the actual cases. This work also illustrates that the MLP can be useful for projections of the main pathways toward sustainable transition. The system-level interaction, particularly the landscape-regime interaction complemented the geothermal causal loop diagram from previous work (Yudha et al., 2022)

This article also provides a novel way to analyze the key aspects of the coal and geothermal landscape, regime, and niche, by employing the qualitative workshop method, which involves major stakeholders with diverse cases of a geothermal system. The information provided by the stakeholders can be used as input to develop the MLP for the geothermal energy sector in the context of the energy transition.

8.6.2. Practical implications

MLP has been used to analyze transitions such as electric vehicles, urban mobility, etc. By combining the supply chain and MLP approach, this article is able to identify the drivers and key enablers that can enhance renewable energy development, or in this case, geothermal energy. This way, geothermal energy is s expected to partially substitute fossil fuel and facilitate the energy transition. The proposed solutions could be used to guide policy-level scenario planning by employing the analyses of geothermal energy sectors in the energy transition context.

8.6.3. Limitations and Recommendations for Future Research

This study used a qualitative approach to obtain and analyze the information from the stakeholders. This study could potentially be a fundamental framework or reference for future research on energy transition that employs a quantitative approach, especially research on enhancing geothermal energy development.

Chapter 9: Thesis conclusion

Facilitating the transition from fossil fuel to renewable energy sources in Indonesia necessitates a thorough examination of the country's energy sector, beginning with the identification and analysis of the current energy regime, progressing to an understanding of energy potentials, and finally to an examination of the preferred clean energy. This research was driven by a gap of knowledge in precedent literature concerning a policy-led supply chain management approach to a renewable energy transition (discussed in Chapter 2).

The initial research began with seeking to understand the current energy regime in Indonesia, which is fossil fuel energy (Chapter 3), which is identifying risks and stakeholders of fossil fuel energy in Indonesia. The approach employed in the research follows the so-called PESTLE analysis. PESTLE analysis consists of the following individual components: political, economic, social, technological, legal, and environmental. This approach allows the identification of multidisciplinary stakeholders and underlying relationships across the sector. The outcomes from the analysis indicated the importance of strategically aligning the stakeholders' policies to the needs of other relevant stakeholders. It is expected that this framework will facilitate an understanding of the dynamics of the problem and it could be used to provoke further research directions.

Following the PESTLE analysis described in Chapter 3, the research continues with the development of a sound understanding of the energy regime that Indonesia is planning to move forward with, which is renewable energy (Chapter 4). This research involves identifying the risks and stakeholders of renewable energy in Indonesia. This research aims to identify the obstacles and unearth the inner workings of the implementation and the distribution of renewable energy, by enacting a PESTLE policy mapping and stakeholder analysis. The main objective is to dissect and analyze the specific relationships of interest within Indonesia's renewable energy sector and holistically approach the need to adequately cover all relevant terrain in the renewable and sustainable energy sector. This is performed by observing agencies or institutions, involved parties, and all relevant stakeholders in the industry with an ultimate goal to better elucidate the various points of dispute among stakeholders and thus come to a recommendation for institutional actors as to how to better promote renewable energy in Indonesia. The results have indicated that existing policies are not yet perfect, given that the renewable energy industry is still minimal, especially in light of falling oil prices. In the future, it is hoped that the government can formulate a breakthrough policy to improve existing policies in the renewable energy sector, such as by giving ease to investors in the renewable energy sector, including the effective and efficient supply chain management of renewable energy.

Having completed the PESTLE analyses (Chapters 3 and 4), the research then focuses on reviewing key enablers and barriers to the transition to renewable energy and identifying the type of renewable energy to focus on (Chapter 5). The work employed a qualitative approach based on a Focus Group Discussion (FGD) as a primary research method, complemented by the document analysis. The participants were chosen due to their expertise and experience in renewable energy development in Indonesia. Their representation encompasses the collective view of stakeholders identified in the previous research in Chapter 4, cutting across the political, economic, social, technological, legal, and environmental (PESTLE) aspects of renewable energy development in Indonesia. The information gained from the FGD gives insights into the outlook and challenges that are central to energy transition within the country, alongside the perceptions of renewable energy development from the influential stakeholders contributing to the process. It is notable that the biggest barriers to transition are centered on planning and implementation aspects, as it is also evident that many in the community do not adhere to the same vision.

Chapter 6 focuses on analyzing geothermal energy being the selected type of renewable energy identified in Chapter 5. The geothermal energy sector is viewed as a complex dynamic system, with complicated issues including technical, financial, infrastructure, and many others. The purpose of Chapter 5 is to analyze and better understand the complex structural nature of geothermal systems in Indonesia. To that end, the chapter examines the geothermal development from a holistic and systematic standpoint, employing the interview approach to enable the conceptualization of the geothermal systems using the System Dynamics (SD) approach. The conceptual model exhibits several underlying and important factors influencing the development of geothermal energy development in Indonesia, such as investment, upstream data to reduce risk, infrastructure, pricing, incentive, ease of permit procedure, environmental concerns, and public acceptance.

Chapter 7 focuses on the development of a conceptual framework to analyze the geothermal energy sector as part of the energy transition complexity that occurs through the different system levels, namely, niche innovation levels, the regime, and the landscape. The socio-technical landscape consists of multiple factors that gives pressure on the energy sectors to perform energy transition, these factors stem from the increasing environmental awareness that was made into national commitments and translated into several regulations and can be applied to a certain part of the energy business processes. The socio-technical regime consists of a series of business processes in the energy supply chain that is divided into upstream, midstream, and downstream processes. The niche innovations highlighted the hot steam from geothermal production as a substitution for steam production from coal burning and emphasized geothermal as a substitute for generating electricity. The transition pathways include several measures that could break down fossil fuel and build up geothermal energy, through a number of schemes and incentives.

9.1. Contributions to knowledge

Three distinct contributions arise from this work; firstly, that of new data and evidence in the field of renewable energy research for developing economies. Secondly, the development and testing of research methods summarised in Chapter 1 are relevant to other sectors. This is particularly relevant for sectors of the infrastructure that are interlinked with political, economic, social, technological, legal, and environmental attributes. Finally, the approach taken is transferrable to other problem sets outside of infrastructure where the observation of policy development and implementation has relevance for many developing economies. In Chapter 4, the fossil energy sector is strongly related to the abovementioned aspects, and it is also applicable to other sectors, such as the renewable energy sector (discussed in Chapter 5), electric vehicles, and many other sectors.

This research also provides a novel way to obtain qualitative and reliable data and information on a sector that is firmly related to stakeholders' involvement. In Chapter 6, the data and information were obtained from a semi-structured, qualitative approach in the form of a Focus Group Discussion participated by major stakeholders, complemented by document analysis. This data-collecting method provides information that is significant, reliable, and representative.

In terms of geothermal research, this research not only complemented the previous works on the geothermal system dynamics model but also addressed the shortcomings in their works, particularly in the robustness of the geothermal system dynamics models' as references in representing the geothermal development in Indonesia. For example, the research in Chapter 7 complemented the work of Aditya (2017) and Setiawan et al. (2020), who identified the key elements of the geothermal SD models. This research addressed the shortcoming in their works as their models were based on a few specific geothermal systems, and not representing other geothermal systems in Indonesia. This research was able to incorporate information from all major geothermal projects that exist in Indonesia as of to date, that are operated by major actors or commercially operating companies. Therefore, it is able to provide a more diverse case of geothermal systems and it also provides a representative geothermal system dynamics model. In addition to that, this research provides a novel way of identifying the complex elements of the geothermal energy businesses, by employing qualitative, semi-structured interviews, involving major stakeholders with diverse cases of a geothermal system.

In terms of transition theory, this work demonstrates the MLP implementation of the sustainable transition, more specifically, in the context of the energy transition. This work extends the work of Geels from 2002 to 2018, and this research also provides the insights that MLP is not just a framework, but it can be implemented for the actual cases, and it is transferrable to other sectors that deal with changes over time. This work also illustrates that the MLP can be useful for projections of the main pathways towards sustainable transition.

Ultimately, this research is also able to create a new collective method, by selecting, linking, and synthesizing different methods into a toolkit, starting from PESTLE (identifying stakeholders and risks for both fossil fuels and renewable energy, stakeholder analysis (extending the works of Rumbayan & Nagasaka (2012) and Tasri & Susilawati (2014)), Causal Loop Diagram (extending Aditya (2017) developed SD technical and economic aspect in 1 area; Setiawan et al. (2020) developed technical, financing using a Computing Classification (CCS) method), and MLP (to illustrate how landscapes pressurize regimes, how niche/innovation could penetrate the regime (extending Geels (2018). In addition to new data and new methods, this series of research also provides a new theory, where the transferable outcomes that arise from the abovementioned tool kit can be used for another context.

9.2. Practical implications

Aside from the contributions to knowledge, this research also provides several practical implications. In terms of its implications on the geothermal sector, the research framework that this research provides can explain the causal structure and interconnections of every aspect of the geothermal energy sector, and it could be used to guide policy-level scenario planning by facilitating analyses of geothermal energy sectors and energy transitions (as provided in Chapters 7 and 8).

In terms of its implication for national policy, this research can potentially be utilized as a toolkit to guide the country's SC transitioning energy strategies, should it be adopted by the Indonesian National Energy Council (DEN). This toolkit has been trialed and will be adopted by government institutions (e.g., Ministry of Energy & Mineral Resources, Ministry of State Planning, Ministry of Finance, Ministry of Environmental & Forestry).

This series of research is also extremely relevant to sustainable international policies and agreements that Indonesia has been part of lately, especially for JTEP (Just Energy Transition Partnership), COP 26, and COP 27. These agreements include climate financing and a new funding mechanism for losses and damage for underdeveloped or developing countries that are vulnerable and suffer losses due to climate change. These mechanisms can accelerate and strengthen the strategies or transition pathways explained in 8.5.3.

This research is transferrable to other sustainable transition problems where policy-led development and implementation have relevance. It can also be used as a toolkit or reference model for other cases, such as the digitalization of hospitals, sustainable tourism, etc.

In addition, a geothermal system can vary depending on many aspects, such as geographical situation, politics, market, etc. This research proposed a framework that could be adopted by governmental institutions and organizations to advance decision-makers in the countries where energy transition that involves geothermal energy can be developed.

9.2. Recommendations for further work

The series of research in this study used semi-structured qualitative approaches, such as a Focus Group Discussion (Chapter 6), interviews (Chapter 7), and a workshop (Chapter 8) to obtain and analyse the information from the stakeholders. Therefore, the framework models and results that this research produces from the qualitative perspective require further quantitative validation. In addition to that, future works could also include integration with quantitative analysis, an extension of the Causal Loop Diagram into full System Dynamics models, as well as the extension of Multi-Level Perspective with probabilistic models.

Nonetheless, this study has demonstrated the robustness of the framework models that can subsequently be adopted as a fundamental reference to complement future research on energy transition that employs quantitative approaches, especially research dealing with enhancing geothermal energy development, energy transitions, and quantitative-based policy roadmaps for various industry sectors.

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Appendix

Appendix to the Chapter 2

2A List of Literature in Original Findings (Chronological Order)

	Title and authorship of articles	Subjects
1.	**Majoras, D.P.** (2014) 'A Summit on Private Environmental Governance: Facing the Challenges of Voluntary Standards, Supply Chains, and Green Marketing', *Environmental Law Reporter: News & Analysis*, 44(2), pp. 10120-10124.	Environmental impact analysis; Sustainability; Nongovernmental organizations; Standard- setting organizations; Advertising -- Self- regulation.
2.	**Mafakheri, F. and Nasiri, F.** (2014) 'Modeling of biomass-to-energy supply chain operations: Applications, challenges and research directions', *Energy Policy*, 67, pp. 116-126.	Biomass energy; Energy research; Fossil fuels; Environmental impact analysis; Renewable energy sources; Biomassproduction; Biomass Electric Power Generation; Other electric power generation; Supply chains.
3.	**Penfield, P.C., Germain, R. and Smith, W.** (2014) 'Assessing the Supply Chain Efficiency of Hardwood Sawmills in New York State throughCase Study Analysis and Data Envelopment Analysis Modeling', *Forest Products Journal*, 64(3/4), pp. 90-96.	Data analysis; New York (N.Y.); Cut Stock, Resawing Lumber, and Planing; Hardwood Veneer and Plywood Manufacturing; Other millwork; Sawmills; Sawmills (except shingle and shake mills); Hardwood industry -- Economic aspects; Supply chain management; Sawmills; Recessions; Profitability.
4.	**Osmani, A. and Zhang, J.** (2014) 'Optimal grid design and logistic planning for wind and biomass based renewable electricity supply chains under uncertainties', *Energy*, 70, pp. 514-528.	Biomass production; Wind power; Wind Electric Power Generation; Other electric power generation; Biomass Electric Power Generation; Optimal designs (Statistics); Renewable portfolio standards; Supply chains; Electricity -- Sales & prices
5.	**Hoggett, R.** (2014) 'Technology scale and supply chains in a secure, affordable and low carbon energy transition', ***Applied** Energy*, 123, pp. 296-306.	Renewable energy transition (Government policy); Carbon; Energy security; Energy policy; Energy research; Regulation and Administration of Communications, Electric, Gas, and Other Utilities; Supply chains.
6.	**Belbo, H. and Talbot, B.** (2014) 'Performance of small-scale straw-to-heat supply chains in Norway', *WIREs: Energy & Environment*, 3(4), pp. 400—407.	Biomass chemicals; Renewable energy sources; Electrical energy; Water power; Norway; Hydroelectric Power Generation; Supply chains.
7.	**Sukumara,** S., **Faulkner, W., Amundson, J. Badurdeen, F. and Seay, J.** (2014) 'A multidisciplinary decision support tool forevaluating multiple biorefinery conversion technologies and supply chain performance', *Clean Technologies & Environmental Policy*, 16(6) pp. 1027-1044.	RESEARCH; Biomass; Decision support systems; Management information systems; Supply chains; Supply & demand.
8.	**Mirabella, N., Castellani, V. and Sala,** S. (2014) 'Forestry operations in the apline context. Life cycle assessment to support the integrated assessment of forest wood short supply chain', *International Journal of Life Cycle Assessment*, 19(8), pp. 1524-1535.	RESEARCH; Biotic communities -- Research; Forestry research; Biodiversity -- Research; Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology); Research and development in the physical, engineering and life sciences; Forest products trucking, long distance; Forest Nurseries and Gathering of Forest Products; Wood; Forest products; Energy consumption; Life cycle costing.

9.	**Mirabella, N., Castellani, V. and** Sala, S. (2014) 'LCA for assessing environmental benefit of eco-design strategies and forest wood short supply chain: a furniture case study', *International Journal of Life Cycle Assessment,* 19(8), pp. 1536-1550.	RESEARCH; Forestry research; Research and development in the physical, engineering and life sciences; Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology); Forest Nurseries and Gathering of Forest Products; Forest products trucking, long distance; Furniture Merchant Wholesalers; Other wood household furniture manufacturing; Nonupholstered Wood Household Furniture Manufacturing; Furniture Stores; Life cycle costing; Forest products; Product life cycle; Furniture industry; Supply & demand.
10.	**Chen, Z. and Su,** S. (2014) 'Photovoltaic supply chain coordination with strategic consumers in China', *Renewable Energy: An International Journal,* 68, pp.236-244.	Photovoltaic power systems; Climatic changes; Consumer behavior; China; Power and Communication Line and Related Structures Construction; Supply chains; Government policy.
11.	**AI-Nory, M.T., Brodsky, A., Bozkaya, B. and Graves, S.C.** (2014) 'Desalination supply chain decision analysis and optimization', *Desalination,* 347, pp. 144-157.	Saline water conversion; Renewable energy sources; Saudi Arabia; Supply chains; Decision making; Strategic planning.
12.	**Belbo, H. and Talbot, B.** (2014) 'Systems Analysis of Ten Supply Chains for Whole Tree Chips', *Forests (19994907),* 5(9), pp. 2084-2105.	Biomass energy; Fuelwood; Forest thinning; Feedstock; Other electric power generation; Biomass Electric Power Generation; Fuel Dealers; Other fuel dealers; Other Miscellaneous Durable Goods Merchant Wholesalers; All Other Miscellaneous Wood Product Manufacturing; Sawmills (except shingle and shake mills); Logging (except contract); All other merchant wholesalers; Supply chains.
13.	**Balaman, S.Y. and Selim, H.** (2014) 'A network design model for biomass to energy supply chains with anaerobic digestion systems', *Applied Energy,* 130, pp. 289-304.	Biomass production; Power resources; Biomass energy; Anaerobic digestion (Sewage purification); Organic wastes; Biomass Electric Power Generation; Other electric powergeneration; Solid Waste Landfill; Other Nonhazardous Waste Treatment and Disposal; Mixed integer linear programming.
14.	**Upadhyay, T.P. and Greibrokk, J.H.** (2014) 'Modeling the importance of biomass qualities in biomass supply chains for bioenergy production', *International Journal of Energy & Environment,* 5(6), pp. 669-678.	Biomass energy industries; Electric power production; Logging; Biomass Electric Power Generation; Fossil Fuel Electric Power Generation; Contract logging; Logging (except contract); Logging; Biomass -- Environmental aspects; Supply chains; Goal programming (Mathematics).
15.	**Grigoroudis, E., Petridis, K. and Arabatzis,** G. (2014) 'RDEA: A recursive DEA based algorithm for the optimal design of biomass supply chain networks', *Renewable Energy.- An International Journal,* 71, pp. 113-122.	Renewable energy sources; Biomass production; Environmental impact analysis; Biomass Electric Power Generation; Supply chains; Algorithms.
16.	**Cambero, C. and Sowlati, T.** (2014) 'Assessment And Optimization Of Forest Biomass Supply Chains From Economic, Social And Environmental Perspectives - A Review Of Literature', *Biomass Bulletin,* 33(4), pp. 97-98.	Forest biomass -- Abstracts; Biomass energy -- Abstracts; Life cycle hypothesis (Economic theory).

17.	**Sosa, A., Acuna, M., McDonneh, K. and Devlin, G.** (2015) 'Controlling moisture content and truck configurations to model and optimise biomass supply chain logistics in Ireland', *Applied Energy,* 137, pp. 338-351.	Biomass; Power resources; Renewable energy sources; Supply chains; Payloads (Aerospace engineering).
18.	**Vermeulen, W.J.V.** (2015)'Self-Governance for Sustainable Global Supply Chains: Can it Deliver the Impacts Needed?', *Business Strategy & the Environment,* 24(2), pp.73-85.	Sustainable development; Administration of General Economic Programs; Supply chain management; Competition (Economics); Business models; Economic development.
19.	**Rafael,** S., **Tarelho, L., Monteiro, A., Sa, E., Miranda, A.I., Borrego, C. and Lopes, M. (2015)** 'Impact of forest biomass residues to the energy supply chain on regional air quality', *Science of the Total Environment,* 505, pp. 640-648.	Forest biomass; Biomass energy; Power resources; Air quality; Renewable energy sources; Biomass Electric Power Generation; Other electric power generation; Nitrogen dioxide -- Environmental aspects.
20.	**Heiss,** S., **Sevoian, N., Conner, D. and Berlin, L.** (2015) 'Farm to institution programs: organizing practices that enable and constrain Vermont's alternative food supply chains', *Agriculture & Human Values,* 32(1), pp. 87-97.	California; Supply chains; Management research; Wholesale prices; Journalism.
21.	**Cambero, C., Sowlati, T., Marinescu, M. and Riiser, D.** (2015) 'Strategic optimization of forest residues to bioenergy and biofuel supply chain', *International Journal ofEnergy Research,* 39(4), pp. 439—452.	Biomass energy; Forests & forestry; Plants -- Residues; Pyrolysis; Biomass Electric Power Generation; Other electric power generation; Mixed integer linear programming.
22.	**Wen, W. and Zhang, Q.** (2015) 'A design of straw acquisition mode for China's straw power plant based on supply chain coordination', *Renewable Energy: An International Journal,* 76, pp. 369-374.	Power plants; Feedstock; Game theory; Power and Communication Line and Related Structures Construction; Supply chains; Energy industries China.
23.	**Rafael,** S., **Tarelho, L., Monteiro, A., Monteiro, T., Gon9aIves, C., Freitas,** S. and **Lopes, M. (2015)** 'Atmospheric Emissions from Forest Biomass Residues to Energy Supply Chain: A Case Study in Portugal', *Environmental Engineering Science,* 32(6), pp. 505-515.	RESEARCH; Renewable energy sources; Power resources; Air quality; Energy conversion; Energy security; Forest biomass.
24.	**Santos, S. and Brandi, H.** (2015) 'Model framework to construct a single aggregate sustainability indicator: an application to the biodiesel supply chain', *Clean Technologies & Environmental Policy,* 17(7), pp. 1963—1973.	RESEARCH; Alternative fuels; Diesel motors -- Alternative fuels; Green diesel fuels; Fuel Dealers; Other fuel dealers; Other basic organic chemical manufacturing; Sustainability; Biodiesel fuels.
25.	**Simoes,** S., **Huppes, G. and Seixas, J.** (2015) 'A Tangled Web: Assessing overlaps between energy and environmental policy instruments along the electricity supply chain', *Environmental* ***Policy &*** *Governance,* 25(6), pp. 439—458.	RESEARCH; Environmental policy; Electricity; Administration of Air and Water Resource and Solid Waste Management Programs; Other provincial and territorial public administration; Regulation and Administration of Communications, Electric, Gas, and Other Utilities; Energy policy; Government policy; Supply chains.
26.	**Paulo, H., Azcue, X., Barbosa-Pévoa, A.P.** and Relvas, S. (2015) 'Supply chain optimization of residual forestry biomass for bioenergy production: The case study of Pomigal', *Biomass & Bioenergy,* 83, pp. 245— 256.	Forest biomass; Renewable energy sources; Portugal; Supply chains; Electrophysiology; Mixed integer linear programming.

27.	**Lautala, P., Hilliard, M., Webb, E., Busch, I., Richard Hess, J., Roni, M., Hilbert, J., Handler, R., Bittencourt, R., Valente, A. and Laitinen, T.** (2015) 'Oppominities and Challenges in the Design and Analysis of Biomass Supply Chains', *Environmental Management,* 56(6), pp. 1397-1415.	Biomass; Biomass energy; Renewable energy sources; Environmental protection; Other electric power generation; Biomass Electric Power Generation; Supply chains.
28.	**Bulman, P.** (2015) 'Tesla's Powerwall battery production requires 'super-charged' supply chain', *Renewable Energy Focus,* 16(5/6), pp. 126-127.	Electric batteries; Solar energy; Energy development; Electrical Apparatus and Equipment, Wiring Supplies, and Related Equipment Merchant Wholesalers; All other merchant wholesalers; Battery manufacturing; Solar Electric Power Generation; Electric charge & distribution; Battery charge measurement.
29.	**Miehailidou, A.V., Vlachokostas, C., Achillas, C., Maleka, D., Moussiopoulos, N.** and Feleki, E. (2016) 'Green Tourism Supply Chain Management Based On Life Cycle Impact Assessment', *European Journal of Environmental Sciences,* 6(1), pp. 30-36.	Climatic changes; Convention and Visitors Bureaus; Recreational and Vacation Camps (except Campgrounds); RV (Recreational Vehicle) Parks and Campgrounds; All Other Traveler Accommodation; Bed-and-Breakfast Inns; Casino Hotels; All Other Amusement and Recreation Industries; Hotels (except Casino Hotels) and Motels; Tourism; Supply chain management.
30.	**Ketikidis, C., Christidou, M., Papadelis, E.C., Grammelis, P., Gypakis, A., Oberwimmer, R.and Kolck, M.** (2016) 'Pilot applications proposal for sustainable woody biomass supply chains', *International Journal ofEnergy Research,* 40(1), pp. 81-90.	Biomass energy; Forest biomass; Potential energy; Other electric power generation; Biomass Electric Power Generation; Supply chains; Stakeholders.
31.	**MoIina-Besch, K. and Piilsson, H.** (2016) 'A Supply Chain Perspective on Green Packaging Development-Theory Versus Practice', *Packaging Technology & Science,* 29(1), pp. 45—63.	Environmental impact analysis; Sustainable development; Waste management; Industrial Design Services; Packaging and Labeling Services; Other Waste Collection; Waste collection; Waste treatment and disposal; Solid Waste Landfill; Administration of General Economic Programs; Supply chains; Packaging -- Environmental aspects.
32.	**Zhang, F., Johnson, D., Johnson, M., Watkins, D., Froese, R., Wang, J.** (2016) 'Decision support system integrating GIS with simulation and optimisation for a biofuel supply chain', *Renewable Energy. An International Journal,* 85, pp. 740-748.	Geographic information systems; Computer simulation; Biomass energy; Other electric power generation; Biomass Electric Power Generation; Decision support systems; Supply chains.
33.	**Klein, D., Wolf, C., Schulz, C. and Weber-Blaschke, G.** (2016) 'Environmental impacts of various biomass supply chains for the provision of raw wood in Bavaria, Germany, with focus on climate change', *Science of the Total Environment,* 539, pp. 45-60.	Biomass; Environmental impact analysis; Energy consumption; Particulate matter; Bavaria (Germany); All Other Miscellaneous Wood Product Manufacturing; Other Miscellaneous Durable Goods Merchant Wholesalers; Wood products.
34.	**Raychaudhuri, A. and Ghosh, S.K.** (2016) 'Lignocellulosic Biomass Supply Chain for Bioethanol Production', *Journal of Solid Waste Technology & Management,* 42(1), pp. 325-335.	Lignocellulose; Biomass energy; Ethanol as fuel; Renewable energy sources; Climatic changes; Biomass Electric Power Generation; Other electric power generation.

35.	**Cao, J., Zhang, X. and Zhou, G.** (2016) 'Supply chain coordination with revenue- sharing contracts considering carbon emissions and governmental policy making', *Environmental Progress & Sustainable Energy,* 35(2), pp. 479—488.	RESEARCH; Global warming; All Other Miscellaneous Store Retailers (except Tobacco Stores); Allother miscellaneous store retailers (except beer and wine-making supplies stores); All other miscellaneous general merchandise stores; Carbon dioxide mitigation; Supply chain management; Revenue sharing (Corporations); Retail industry.
36.	**Ba, B.H., Prins, C. and Prodhon, C.** (2016) 'Models for optimization and performance evaluation of biomass supply chains: An Operations Research perspective', *Renewable Energy: An International Journal,* 87, pp. 977-989.	Biomass energy; Biomass Electric Power Generation; Other electric power generation;Process, Physical Distribution, and Logistics Consulting Services; Process optimization; Performance evaluation; Operations research; Supply chain management.
37.	**De Meyer, A., Cattrysse, D. and Van Orshoven, J.** (2016) 'Considering biomass growth and regeneration in the optimisation of biomass supply chains', *Renewable Energy.- An International Journal,* 87, pp. 990-1002.	Biomass; Anaerobic digestion (Sewage purification); Renewable energy sources; Supply chain management; Mixed integer linear programming.
38.	**Woo, Y., Cho,** S., **Kim, J. and Kim, B.S.** (2016) 'Optimization-based approach for strategic design andoperationofabiomass-to-hydrogen supply chain', *International Journal ofHydrogen Energy,* 41(12), pp. 5405-5418.	Biomass; Renewable energy sources; Hydrogen -- Analysis; Supply chains; Process optimization; Decision making.
39.	**Zhisong, C. and Shong-lee, I.S.** (2016) 'The joint bargaining coordination in a photovoltaic supply chain', *Journal of Renewable & Sustainable Energy,* 8(3), pp. 1-14.	Photovoltaic power generation; Photovoltaic power systems; MATHEMATICAL models; Power and Communication Line and Related Structures Construction; Supply chains; Supply chain management; Subsidies; Collective bargaining.
40.	**Mayerle, S.F., Neiva de Figueiredo, J.** (2016) 'Designing optimal supply chains for anaerobic bio-digestion/energy generation complexes with distributed small farm feedstock sourcing', *Renewable Energy. An International Journal,* 90, pp. 46-54.	Biodegradation; Feedstock; Renewable energy sources; Biomass energy; Waste management; Biomass Electric Power Generation; Other electric power generation; Solid Waste Landfill; Other Waste Collection; Waste collection; Waste treatment and disposal.
41.	**Zhang, F., Johnson, D.M. and Wang, J.** (2016) 'Integrating multimodal transport into forest-delivered biofuel supply chain design', *Renewable **Energy: An** International Journal,* 93, pp. 58-67.	TRANSPORTATION; Feedstock; Mainline freight rail transportation; Biomass energy; Containerization; Mixed integer linear programming; Decision making.
42.	**Azadeh, A., Vafa Arani, H.** (2016) 'Biodiesel supply chain optimization via a hybrid system dynamics-mathematical programming approach', *Renewable Energy. An International Journal,* 93, pp. 383—403.	MATHEMATICAL models; Biomass energy -- Environmental aspects; Renewable energy sources; Biodiesel fuel manufacturing; Other basic organic chemical manufacturing; Hybrid systems; Biodiesel fuel supply & demand; Mixed integer linear programming.
43.	**Murphy, F., Sosa, A., McDonnell, K. and Devlin, G.** (2016) 'Life cycle assessment of biomass-to-energy systems in Ireland modelled with biomass supply chain optimisation based on greenhouse gas emission reduction', *Energy,* 109, pp. 1040—1055.	Biomass energy; Greenhouse gas mitigation; Renewable energy sources; Energy industries; Ireland; Biomass Electric Power Generation; Other electric power generation; Supply chains.

44.	**Saif, Y. and Almansoori, A.** (2016) 'A capacity expansion planning model for integrated water desalination and power supply chain problem', *Energy Conversion & Management,* 122, pp. 462—476.	Saline water conversion; Power resources; Integrated water development; Cogeneration of electric power & heat; Renewable energy sources; Thermal expansion.
45.	**N/A (Periodical).** (2016) 'Sustainable Biogas Supply Chain', *BioCycle,* 57(9), pp. 13-14.	Biogas; Supply chain management.
46.	**Rentizelas, A.A. and Li, J.** (2016) 'Techno-economic and carbon emissions analysis of biomass torrefaction downstream in international bioenergy supply chains for co- firing', *Energy,* 114, pp. 129-142.	Biomass energy industries; Energy conversion; Energy economics; Renewable energy sources; Biomass Electric Power Generation; Co- combustion.
47.	**Nasiri, F., Mafakheri, F., Adebanjo, D., Haghighat, F.** (2016) 'Modeling and analysis of renewable heat integration into non- domestic buildings - The case of biomass boilers: A whole life asset-supply chain management approach', *Biomass & Bioenergy,* 95, pp. 244-256.	conditioning equipment andsupplies merchant wholesalers; Heating Equipment (except Warm Air Furnaces) Manufacturing; Boilers; Supply chain management.
48.	Park, D.H., Kashyap, P. and Visvanathan, C. (2016) 'Comparative assessment of green supply chain management (GSCM) in drinking water service industry in Lao PDR, Thailand, and South Korea', *Desalination & Water Treatment,* 57(59), pp. 28684-28697.	Drinking water; Drinking water treatment units; Supply chain management.
49.	**Lin, C.K. and Moffat, P.A.** (2017) 'Global Supply Chain under the Paris Agreement: The Relevance of Chemical and Product Regulations', *Natural Resources & **Environment,*** **31(3),** pp. 21-25.	Climatic changes -- Law& legislation; Global warming -- Government policy; Greenhouse gases -- Environmental aspects; Greenhouse gases -- Prevention; Ecology -- Safety measures.
50.	**Ng, R.T.L. and Maravelias, C.T.** (2017) 'Design of biofuel supply chains with variable regional depot and biorefinery locations', *Renewable Energy: An International Journal,* 100, pp. 90—102.	Biomass; Linear programming; Linear substitutions; Mathematical optimization; Mass (Physics).
51.	**Calderñn, A.J., Agnolucci, P. and Papageorgiou, L.G.** (2017) 'An optimisation framework forthestrategicdesign ofsynthetic natural gas (BioSNG) supply chains', *Applied Energy,* 187, pp. 929-955.	Synthetic natural gas; Energy crops; Plantations; Supply chains; Mixed integer linear programming.
52.	**Chen, Y., He, L., Guan, Y., Lu, H. and Lu,** J. (2017) 'Life cycle assessment of greenhouse gas emissions and water-energy optimization for shale gas supply chain planning based on multi-level approach: Case study in Barnett, Marcellus, Fayetteville, and Haynesville shales', *Energy Conversion& Management,* 134, pp. 382-398.	Greenhousegasmitigation; Energyeconomics; Environmental security; Shale gas; Supply chains.
53.	**Hanes, R. and Carpenter, A.** (2017) 'Evaluating oppominities to improve material and energy impacts in commodity supply chains', *Environment Systems & Decisions,* 37(1), pp. 6-12.	Energy consumption; Emissions (Air pollution); Industrial Process Furnace and Oven Manufacturing; Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables; Commodity chains; Supply chains; Manufacturing processes.

Appendix to the Chapter 6

6A Summary of quotes from the interviewees and their associated CLD loops

Statements	Source (Interviewee)	CLD Loop
More certainty of geothermal exploration will reduce the risk of geothermal exploration	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 10	B1, B3
To obtain more detailed information and data resolution, a geothermal area with lower risk would require further study and data integration	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 10	B3
The more risk of a geothermal project will potentially increase the capital cost due to project loss	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 10	B1, B3
Clear risk of geothermal exploration enables the bankability of a geothermal project	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C	B1, B3
The capital cost of geothermal exploration determines the attractiveness	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 10	B1
Geothermal investment depends on the geothermal attractiveness and its bankability	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 10	B1
Geological, Geophysical, and Geochemical (3G) surveys are important for determining certainty in exploration	1A, 1B, 1C, 2, 3A, 1B, 4, 5A, 5B, 5C, 6A, 6B, 6C	B3
Government-funded exploration can reduce the capital cost and increase the attractiveness	2, 3A, 3B, 5A, 5B, 5C, 6A, 6B, 6C, 7	B1
Upstream data integration is needed to solve the issues about the certainty of geothermal exploration	1A, 1B, 1C, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C	B3
Geothermal investment depends on the bankability and attractiveness of geothermal projects	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 10	B1
Building geothermal infrastructures cost a lot	1A, 1B, 1C, 2, 3A, 3B, 5A, 5B, 5C, 6A, 6B, 6C, 10	B2
Power wheeling is one of the key points in reducing the capital cost of geothermal	1A, 1B, 1C, 3A, 3B, 5A, 5B, 5C, 8	B2
Government regulations and interventions are needed in terms of solving the geothermal issues	1A, 1B, 1C, 2, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8, 9, 10	R1, R2, R3
Easier permit regulation will lead to increasing geothermal development	1A, 1B, 1C, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C	R3
The more developed geothermal projects could potentially generate income as Tax and Non-Tax Income that would be beneficial for supporting the Government	1A, 1B, 1C, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7	R1, R2, R3
Pricing regulation is needed to increase the geothermal attractiveness	1A, 1B, 1C, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7	R2
Incentives will increase geothermal attractiveness	1A, 1B, 1C, 2, 3A, 3B, 3C, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7	R1
The better environmental risk assessment and mitigation plans will ease the permit processing.	1A, 1B, 1C, 3A, 3B, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7	B4, R3

Incorporating socioeconomic factors with the right communication, education and counselling could increase public acceptance of the geothermal projects	4, 6A, 6B, 6C	B4, R4
Public acceptance of geothermal projects can ease the development	4, 6A, 6B, 6C	B4, R4

Appendix to the Chapter 7

7A Summary of workshop

Statements	Aspects	MLP Elements	Source (Participant)
Indonesia has abundant sources of energy, but still relies on declining fossil fuel	Increasing Energy Demand and Depletion of Fossil Energy Resources	Socio-technical Landscape	5A, 5B, 5C
Changes in consumption without further exploration would lead Indonesia closer to an energy crisis			2, 4, 6A, 6B
Indonesia's abundant renewable energy reserves force Indonesia to move away from fossil energy.			2, 4, 5A, 5B, 5C, 6A, 6B
Indonesia needs to diversify its energy supply and increase energy efficiency			2, 4, 5A, 5B, 5C, 6A, 6B
Energy demand is one of the vital reasons to move forward with the energy transition			1A, 1B, 1C, 2, 3A, 3B, 3C, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8, 9, 10
The only way to move forward is to reduce dependence on coal and gas, instead of increasing more fossil energy and optimizing renewable energy	Growing Environmental Awareness		1A, 1B, 1C, 2, 3A, 3B, 3C, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8, 9, 10
The issue of climate change is a global problem			1A, 1B, 1C, 2, 3A, 3B, 3C, 4, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8, 9, 10
Indonesia has ratified the Paris Agreement and pledged to reduce carbon emission			3A, 3B, 3C
Optimization of geothermal energy should be a priority for transition energy			1A, 1B, 1C, 2, 3A, 3B, 3C, 4, 5A, 5B, 5C, 6A, 6B
Updated NDC emphasizes the importance of energy transition and geothermal energy's role in helping tackle the climate issue.			7, 8, 9
Fully transitioning towards renewable energy from fossil energy will take some time			1A, 1B, 1C, 2, 3A, 3B, 3C, 4,

			5A, 5B, 5C, 6A, 6B, 7
Indonesia needs to utilize other sources while the renewable energy sources become gradually viable on an economic scale			5A, 5B, 5C
Geothermal energy operation is one of the most environmentally friendly			5A, 5B, 5C
The national commitments that the Government of Indonesia has made, should be translated as government interventions through policies or regulations.			5A, 5B, 5C
Utilising geothermal to its full potential could be the main key to partially substituting fossil fuels such as coal.			5A, 5B, 5C
Indonesia has quite a number of regulations that supports the energy transition	Energy Transition Regulations and Schemes		2, 10
The DMO scheme would be discouraging from the perspective of the producers			6A
The coal specification scheme would also limit the usage of coal for coal power plants as it only allows certain types of coal to be used for generating electricity			6B
The Government of Indonesia has planned to phase out the coal power plant by 2040			8
The Government of Indonesia needs to find a mechanism that can optimise the financing issues to attract investments or incentives, which could be fiscal and non-fiscal incentives			10
Fiscal incentives could be in the form of tax holidays, tax allowance, import duty facilitation, etc			10
Non-fiscal incentives such as government-funded drilling and power wheeling schemes			10
Indonesia is planning to implement the Energy Transition Mechanism (ETM).			2
The ETM consists of two schemes, namely the Carbon Reduction Facility (CRF), which is used to retire coal-fired power plants early in Indonesia, and the other one is Clean Energy Facility (CEF) scheme, which is aimed to develop or reinvest green energy facilities			2
The upstream process starts with preliminary surveys and coal	Energy Supply Chain and	Socio-technical Regime	8

exploration to find a potential coal source and reserve. Once they are identified, the land was cleared and the topsoil that covered the reserve was removed.	Business Processes		
The exploitation starts by performing coal blasting, drilling, and coal will be eventually collected through mining using heavy equipment. The coals are then processed through the crushing, sorting, and washing phase.			8
The mid-stream process continued by transporting the coal to a loading area or storage before the retails and is eventually consumed			8
When it comes to electricity generation, the midstream processes continue by burning the coal to produce steam. The steam is used to power the turbine that generates electricity.			8
Following the electricity generation, the electricity is then transmitted, distributed and eventually consumed by the end consumers.			8
The early phase of the geothermal operation (upstream) consists of the exploration			4, 5A, 5B, 5C, 6A, 6B
Following the surveys and the tests, the assessed geothermal working area will undergo several bureaucratic processes			1A, 1B, 1C, 2, 3A, 3B, 3C, 4, 6A, 6B
Pre-Transaction Agreement (PTA) Signing can be optional to discuss the price range of the geothermal products			8
Feasibility study of the geothermal project, well developments and power plant construction follows the obtaining of the permit			1A, 1B, 1C, 8
Power Purchase Agreement (PPA) determines the price of electricity produced from the area			2, 8
Following the PPA: geothermal project utilization, geothermal production to produce steam, processing them, and ultimately generating the electricity			1A, 1B, 1C, 3A, 3B, 3C, 4, 5A, 5B, 5C, 6A, 6B, 7
Following the upstream processes, the electricity produced will undergo a midstream process, as they are transmitted and distributed through transmission facilities			8
The geothermal supply chain ends in a downstream process as it was			8

distributed to consumers (households, industry, etc).			
The domestically manufactured technology could be implemented with less cost since they are not imported, and increase the geothermal energy development.	Potentials from Geothermal	Niche Innovations	5A, 5B, 5C, 9
Geothermal can potentially create more ecosystems, such as electric vehicles (EV), green industry, clean cooking, and other ecosystems.			5A, 5B, 5C