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Sustainable Transition from Fossil Fuel to Geothermal Energy: A Multi-Level Perspective Approach

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

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1. Introduction

Energy is essential for economic development and human well-being, and it is inseparably linked to the challenges of sustainable development [1,2]. With the growing concerns of 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 tracked, particularly in European countries [3–5] and the U.S. [6]. There are numerous empirical and conceptual studies that 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 [2–6]. 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 [2].

On a global scale, the utilization of renewable energy as the most critical aspect 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 6000 inhabited islands [7]. Based on the analysis carried out previously [8,9], geothermal energy has been identified as the most suitable type of renewable energy to develop in Indonesia [10]. 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 [11,12]. According to research estimates, Indonesia possesses one of the world's largest geothermal energy potentials, accounting for approximately 28,617 MW [13]. These make it favorable for Indonesia to maximize the utilization of geothermal energy as key to a 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 [14]. Particularly in geothermal energy, its development is linked to a complex system that includes stakeholders, institutions, regulations, technologies, and other interconnected and changing aspects [15]. 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, this research focuses on how to facilitate and accelerate the journey of the energy transition. Answering this question requires 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 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, and 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 information obtained 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.

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 required.

Over the decades, numerous studies have emerged on the socio-technical transition [16–19], driven by various societal issues caused by climate change, conventional energy resource depletion, urban eco-life and sustainability, biodiversity, etc. In recent years, there have been trends 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 [20]. Therefore, an improved performance in multiple sectors requires socio-technical systems as the main focal analysis unit [21]. Changes in such systems are based on mechanisms of societal and technological co-evolution [21].

Extant literature has demonstrated how a change in socio-technical systems occurs, which includes the patterns and dynamics that may lead to transitions or structural transformation of these systems [17–19,22–24]. The MLP approach [19,22,23] 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 [17,24]. 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) [25], urban mobility or transport studies [26], e-governance systems [27], technological innovation [28], and agriculture systems [29].

On the micro-level, the niche is a protective space where radical innovations are taking place [30]. The niche acts as an incubation room from normal market forces, which allows research and learning through experience [31,32]. However, developing the niches requires a number of factors, such as lead markets, the right space for early acceptance and experimentation, and funding for research demonstration and learning [31]. The niche level can provide space and time for supporting networks to be established [30].

On the meso-level, or the socio-technical regime level, the rules that reproduce the various aspects of socio-technical systems are established [33]. This level includes the 'rule-set or grammar' of processes, technologies, skills, corporate cultures, and artefacts that are embedded in institutions and infrastructures [34]. 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 [23,35].

The macro-level or socio-technical landscape includes a much wider context that influences both the niche and socio-technical regime levels. The socio-technical landscape forms the external structure or context for the interactions of actors [36]. Some examples of the socio-technical landscapes are economic growth, wars, immigration, broad political coalitions, cultural norms, and environmental problems and paradigms [23,35,37].

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 [38]. 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 [39]. In niche-regime interactions, niche innovations gain internal momentum through several factors, such as learning processes, support from powerful groups, and price/performance improvements [23,39]. In addition to that, the destabilization of the regime that took place during the transition can create windows of opportunity for niche innovations [21,39].

3. Methodology

This research is focused on developing a conceptual framework to analyze the energy transition complexity that occurs through the developments on different system levels, namely, niche innovation levels, the regime, and the landscape. The overall research process, thus, 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 to discuss a particular subject with a group of people (in this case the stakeholders in geothermal energy) who share their knowledge and experience [40]. 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 [40]. The participants were provided with the opportunity to identify and analyze a certain topic and ultimately come up with a collective decision or consensus [40,41] and can generate data that can be both descriptive and explanatory [42,43]. This method is frequently used as a qualitative approach to gain an in-depth understanding of complex issues [44,45].

The workshop was attended by geothermal stakeholders in Indonesia. These participants represent the seven largest geothermal companies that are commercially operating in Indonesia. In addition to these participants, the workshop also included representatives from a state-owned electricity company, the National Research and Innovation Agency, and the 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' names are anonymized (Table 1).

Table 1. 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 × 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 × 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 1877 MW: with 672 MW from its own operations and 1205 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 5A	Geothermal company; Director: Making major corporate decisions and managing the company's overall resources and geothermal operations
		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.

Table 1. *Cont.*

Case	Brief Company Profiles	Code	Type of Company; Position of the Participant: Job Description
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 × 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, is 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.

4. Findings

In this section, several key issues on the stakeholder's uptake of the energy transition will be elaborated: (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.

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 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% of energy comes from coal, 19.36% from natural gas, 34.38% from oil, and 10.9% from new and renewable energy.

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 the Indonesia's domestic energy sources are relatively abundant, especially for the coal and natural gas sectors. 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.

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 emissions, or even zero-carbon emissions. 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 emissions, or even zero-carbon emissions.

During the Conference of Parties (COP) 21 in 2015, known as the 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 resulted in Indonesia ratifying Law No 16/2016 about the Ratification of the Paris Agreement to The United Nations Framework Convention on Climate Change. Participant 3A also stated that any measures that need to 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 such as 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 1185 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 the 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 energy 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 a 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 "Clean Energy". Participant 5B suggested that utilizing geothermal energy to its full potential could be the main key to partially substituting fossil fuels such as coal.

4.3. Energy Transition Regulations and Schemes

According to Participant 2, there have been several regulations that have been the legal basis for the energy transition in Indonesia. These regulations are:

- Law No 30/2007 about energy;
- Law No 30/2009 about electricity;
- Governmental Regulations 79/2014 about the 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 the national energy plan.

In addition to these regulations, specific for geothermal energy, Participant 10 also added that Law No 21/2014 about Geothermal have 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 and the MEMR Decree 139/2021 about the domestic coal demand fulfilment and coal specification, is 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 a 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 the developer as the seller and PLN as the buyer. Therefore, the government needs to find a 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) scheme, which is used to retire coal-fired power plants early in Indonesia, and the Clean Energy Facility (CEF) scheme, which is aimed to develop or reinvest in 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.

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. During 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 described the coal energy supply chain as a lengthy process that begins with the 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 entering the market 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 the 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 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. 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 is distributed to consumers (households, industry, etc.).

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 9 confirmed that there has been recent research that involved 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 of Company 5 has been able to enhance local agricultural production. Utilizing geothermal steam 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

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

Based on the findings (see also Table A1 on Appendix A), this section will discuss the energy transition from a multi-level perspective (MLP), which consists of (Section 5.1) elements of MLP, (Section 5.2) system-level interactions, and (Section 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 1 shows the MLP for coal energy as the old regime, while Figure 2 illustrates the MLP for geothermal energy as the new regime.

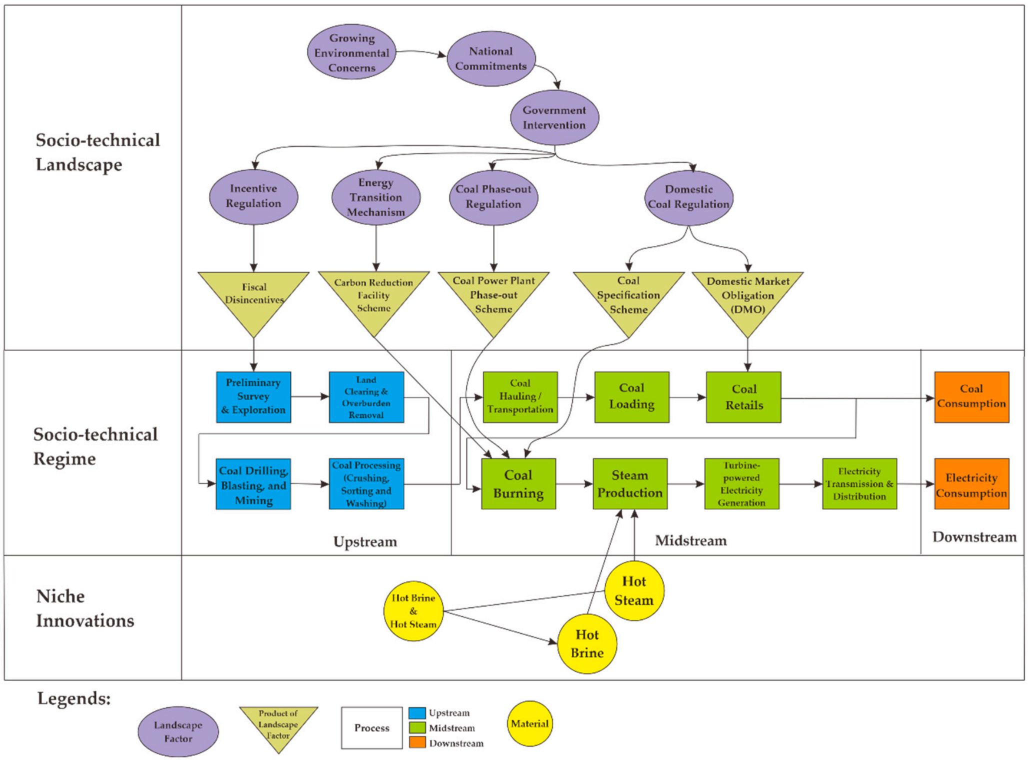

Figure 1. MLP diagram for coal energy as the old regime.

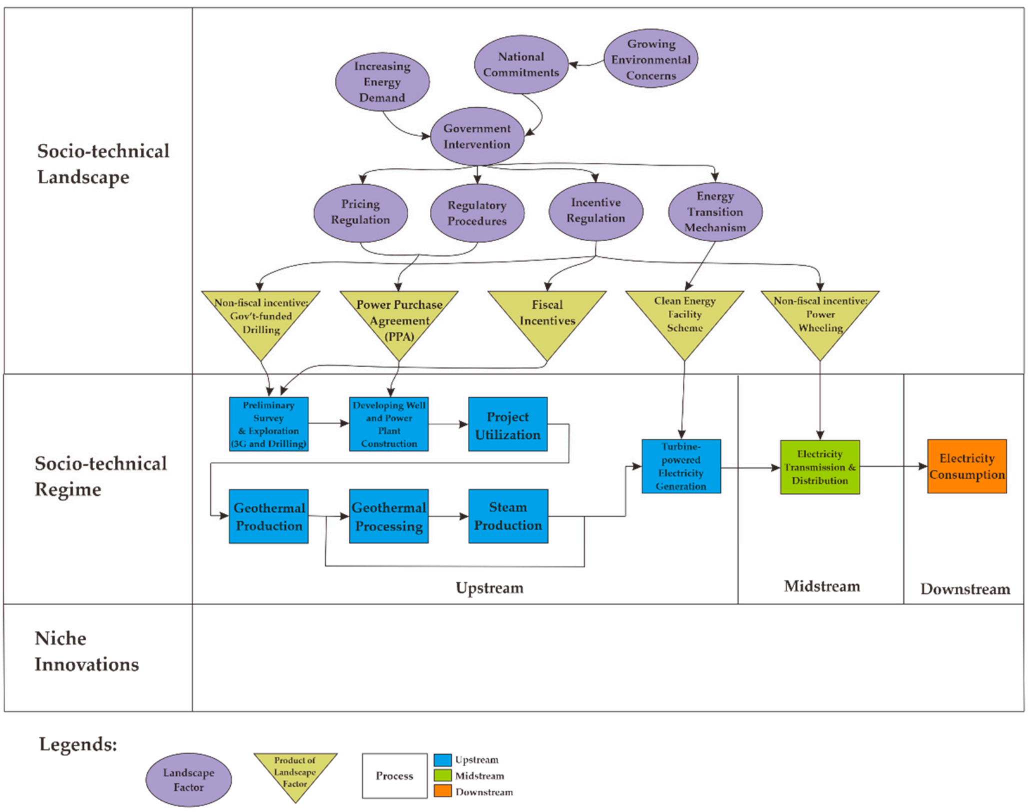

Figure 2. MLP diagram for geothermal energy as the new regime.

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 [46]. In this section, the components of each level of the MLP for both old and new regimes will be discussed.

5.1.1. Socio-Technical Landscape

On the macro level, the socio-technical landscape consists of several landscape factors (the purple ellipses) that provide pressures 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 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) [47].

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 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 it requires 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 on the market and consumed by the end consumers, which could be residential, business, industrial, and public.

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 steams, 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 eventually be distributed to the end consumers through the electricity network system. For the downstream process, the distributed electricity will be on the market and consumed by the end consumers.

5.1.3. Niche Innovations

At the micro level, niche innovations consist of material transformation (yellow circles) 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.

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.

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 to destabilize the coal regime. As of 2022, the Government of Indonesia planned to only incentivize '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 retail and discourages the overall mining business. In addition, the Government of Indonesia also plans to start by decommissioning a quarter of its coal capacity by 2030 in an effort to phase out coal 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 the 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, the 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, a scheme is needed 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.

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 mainly comes from coal burning, which results 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.

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 also be 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.

5.3. 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 3). 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.

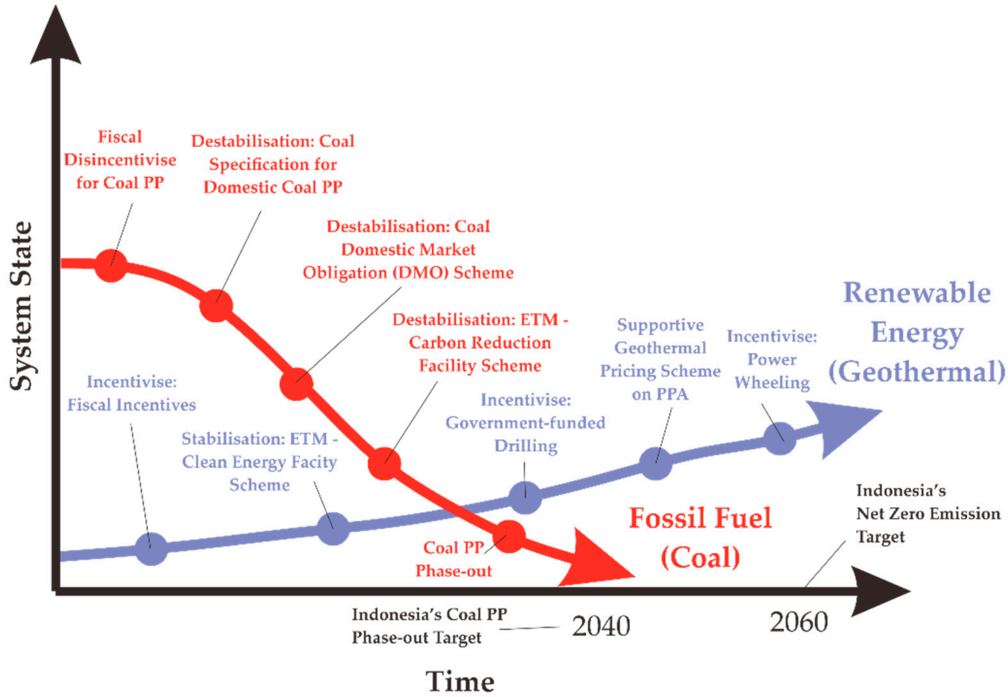

Figure 3. Illustration of the transition pathways of the coal and geothermal energy sector.

Figure 3 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 be used to generate electricity from the power plant. In addition, 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 fulfil 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 a 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 [48,49], which results in the coal curve plummeting down by 2040 (Figure 3, 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.

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 [50]. 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.

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, which is executed through several regulations that are meant to boost geothermal energy 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 incentivization in non-fiscal aspects, in order to achieve Indonesia's Net Zero Goal in 2060.

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, and 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 our previous work [47].

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.

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 expected to partially substitute fossil fuel and facilitate the energy transition. The proposed solutions could be used to guide the policy-level scenario planning by employing the analyses of geothermal energy sectors in the energy transition context.

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.

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Appendix A

Table A1. Summary of the 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

Table A1. *Cont.*

Statements	Aspects	MLP Elements	Source (Participant)
Indonesia needs to diversify its energy supply and increase energy efficiency	Increasing Energy Demand and Depletion of Fossil Energy Resources		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		Socio-technical Landscape	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
Utilizing 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 optimize 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 could be in the form of 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 Clean Energy Facility (CEF) scheme, which is aimed to develop or reinvest in green energy facilities			2
The upstream process starts with preliminary surveys and coal 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	Energy Supply Chain and Business Processes	Socio-technical Regime	8
The exploitation starts by performing coal blasting, drilling, and coal will be eventually collected through mining using heavy equipment; then, the coals are 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 retail and is eventually consumed			8
When it comes to electricity generation, the midstream processes continue by burning the coal to produce steam, which 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

Table A1. *Cont.*

Statements	Aspects	MLP Elements	Source (Participant)
The early phase of the geothermal operation (upstream) consists of the exploration	Energy Supply Chain and Business Processes	Socio-technical Regime	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
A 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 and geothermal production to produce steam are conducted. These processes are then continued with steam processing, 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 distributed to consumers (households, industry, etc.)			8
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

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