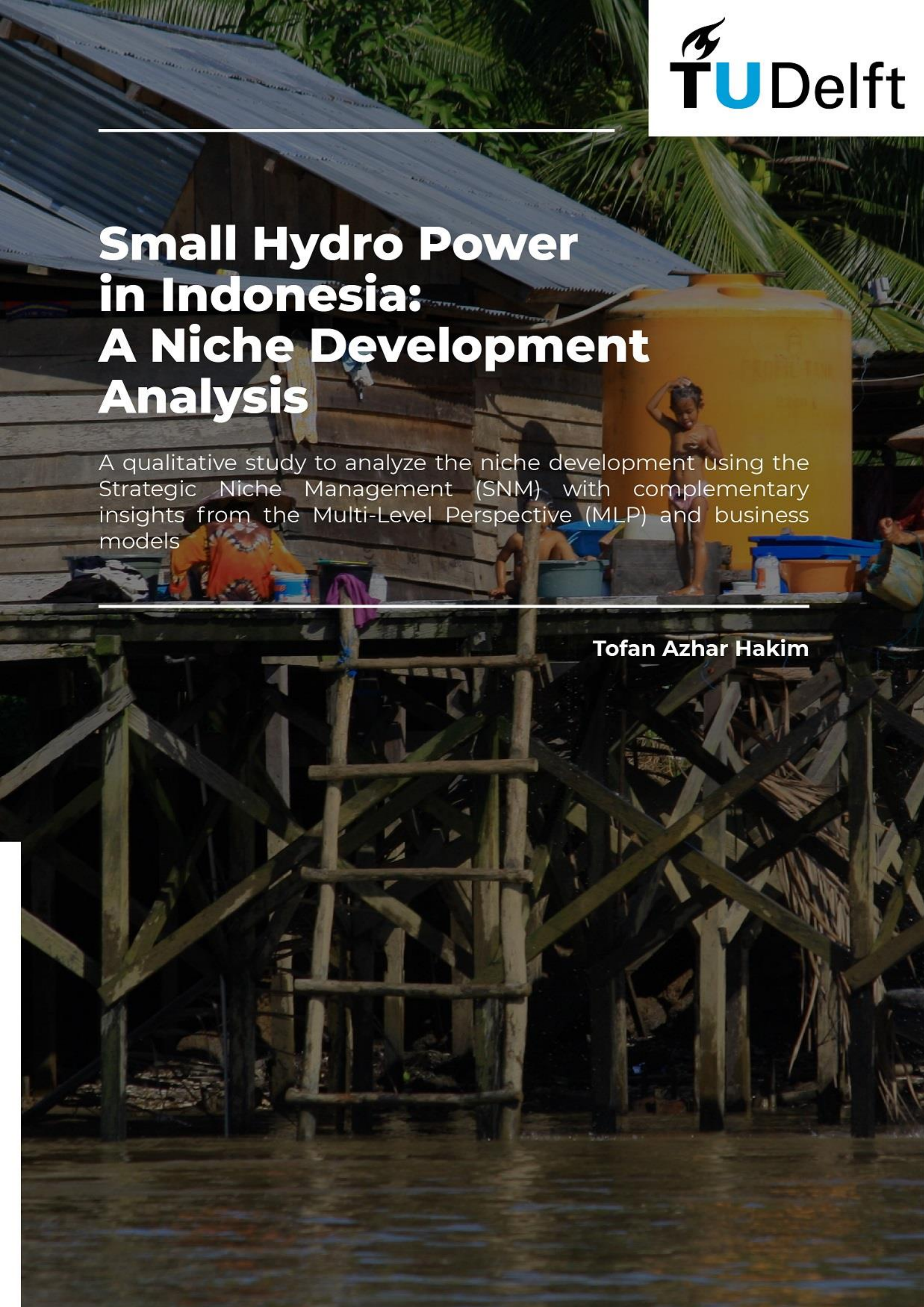

Small Hydro Power in Indonesia: A Niche Development Analysis

A qualitative study to analyze the niche development using the Strategic Niche Management (SNM) with complementary insights from the Multi-Level Perspective (MLP) and business models

Tofan Azhar Hakim

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Tofan Azhar Hakim
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Executive Summary

Problem statement

To reduce carbon emissions by 29% by 2030 and achieve the renewable energy target of 23% by 2025, Indonesia needs to utilize more renewable energy. Although Indonesia is endowed with many renewable energy resources such as hydro, solar, wind and biomass, renewable energy currently only accounts for 14.37% of the total power generation installed capacity (Directorate General of Electricity, 2021). Of these renewable energy sources, Indonesia has a large potential for small hydro power that can be developed, particularly for rural electrification. Around 19,385 MW of small hydro power potential lies across the Indonesian archipelago (ESDM, 2017). However, it has not been harnessed optimally where only 0.6% of the total potential contributes to the overall power plant installed capacity in Indonesia.

Although international donors and development agencies have conducted small hydro power experiments in Indonesia since the 1990s, the contribution of small hydro power is currently still low. Therefore, it is necessary to study the development of small hydro power in Indonesia to gain insights into actors and factors that have influenced the development, address the sociotechnical aspects of niche development and identify barriers and opportunities for broader adoption. Furthermore, given the diversity of small hydro power business models implemented in Indonesia, it is necessary to analyze how business models contributed to small hydro power niche development.

Research methodology

This research takes a qualitative approach to analyze niche development using the Strategic Niche Management (SNM) with complementary insights from the Multi-Level Perspective (MLP) and business models. Therefore, as an analytical framework, this thesis builds an integrated analytical framework with the schematic MLP diagram as a foundation to analyze inter dynamics between the landscape, the regime and the niche from the 1990s. At the niche level, the SNM framework is used to provide comprehensive analysis in niche development. In addition, Osterwalder and Pigneur's business model components are used to describe four business models of small hydro power in Indonesia. A case study research approach is chosen to gain insights into niche development and analyse different business models implemented in West Java. The data collection method includes interviews with 12 informants representing different groups of actors in the small hydro power sector and secondary data analysis. The research methodology is developed to answer the main research question in this thesis:

"How has the small hydro power market niche developed in Indonesia and how did business models facilitate niche development?"

Main findings

The results show that the small hydro power niche was developed in the 1990s through grants and technical assistance from international donors and development agencies driven by low rural electrification in developing countries as a landscape factor. The learning process in the niche improved the capability of local engineers who established local turbine manufacturers. The positive expectations from a successful experiment attracted more actors to be involved in the niche development and increase the composition of actors covering the entire small hydro power supply chain. PLN stopped the rural electrification program after financial problems due to the Asian Financial Crisis 1998. At the same time, it created windows of opportunity for niche actors to develop small hydro power in rural areas. The pressure from the international community to mitigate climate change influenced the formulation of the Indonesia Nationally Determined Contribution (NDC) of the Paris Agreement 2015. It also influences the renewable energy target set in the National Energy General Plan (RUEN), in which the government aims to increase the utilization of renewable energy by 23% in 2025. Therefore, small hydro power is expected to contribute more to the total energy mix.

Several factors hampered the development of small hydro power, including regulation, financial, policy, social, and technology. Private investors perceive small hydro power as an uncertain sector due to frequent regulation changes. Therefore, private investors are reluctant to invest and adopt the "wait and see" strategy. In terms of the economy of scale, micro hydro power is too small for private investors and hence not commercially viable. In addition, banks do not have the capability to evaluate small hydro power projects' technical and economic feasibility. In terms of policy, the government's commitment to the 35 GW project that coal-fired power plants dominate creates an entry barrier for small hydro power. Furthermore, small hydro power plants are often installed in customary land. It usually leads to tenurial conflict with indigenous communities for land acquisition. Currently, local turbines manufacturers are able to produce micro hydro power turbines. However, limited production infrastructure becomes a barrier for local turbine manufacturers to produce turbines with more than 1 MW capacity.

Niche actors have implemented business models to overcome adoption barriers of small hydro power in Indonesia. The cooperative business model emerges as the implementation of micro hydro power plant projects using grants in rural areas needs the active participation of the local community to improve operation sustainability. The Public-Private Partnership (PPP) business model is developed to overcome the financial barrier of the project funded by a grant through a partnership with the private firm. Furthermore, the IPP business model has emerged as incremental improvement in the regime sociotechnical dimensions that facilitate niche development.

Reflections

Through integrating three frameworks in an analytical framework, this research provides a comprehensive analysis of the Indonesia small hydro power niche, rich information on business models, and inter dynamic between landscape factors, sociotechnical regime and the niche. Throughout the small hydro power niche development, different business models have been developed through learning processes and network formation among actors involved in niche development.

Recommendations

A more significant contribution of the small hydro power plant in the electricity sector is expected in the future. This thesis shows that the Indonesian policymakers need to use shielding concepts from the SNM framework to formulate policies and regulations that support niche development. Passive shielding should be applied by prioritizing small hydro power development for rural areas with local hydro power potential. In addition, active shielding can be implemented through formulating regulations that reduce the complexity of permits and licenses procedure for small projects that can attract private investments. Coal subsidies should be reduced to make the cost of production (BPP) of small hydro power more competitive.

Key words: Small Hydro Power, Indonesia, Strategic Niche Management, Multi-Level Perspective, Business Model

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List of Acronyms

ADB	:	Asian Development Bank
AHB	:	Asosiasi Hidro Bandung (Hydro Bandung Association)
AMDAL	:	Analisis Manajemen Dampak Lingkungan (Environmental Impact Management Analysis)
BOO	:	Build Own Operate
BOOT	:	Build Own Operate Transfer
BPP	:	Biaya Pokok Produksi (Cost of Production)
BPPT	:	Badan Pengkajian dan Penerapan Teknologi (Agency for the Assessment and Application of Technology)
DEN	:	National Energy Council
DGNREEC	:	Directorate General of New and Renewable Energy and Energy Conservation
ESDM	:	Energi dan Sumber Daya Mineral (Ministry of Energy and Mineral Resourcespltm)
GHG	:	Greenhouse Gas
GIZ	:	Deutsche Gesellschaft fur Internationale Zusammenarbeit (German Society for International Cooperation)
GTZ	:	Deutsche Gesellschaft fur Technische Zusammenarbeit GmbH
GW	:	Giga Watt
IPP	:	Independent Power Producer
MEMR	:	Ministry of Energy and Mineral Resources
MLP	:	Multi-Level Perspective
MW	:	Mega Watt
NDC	:	Nationally Determined Contribution
IBEKA	:	The People-Centered Business and Economic Institute
JICA	:	Japan International Cooperation Agency
KEN	:	Kebijakan Energi Nasional (National Energy Policy)
kW	:	Kilo Watt
kWh	:	Kilo Watt Hour
PLN	:	Perusahaan Listrik Negara
PLTA	:	Pembangkit Lstrik Tenaga Air (Large Hydro Power Plant)
PLTMH	:	Pembangkit Listrik Tenaga Mikro Hidro (Micro Hydro Power Plant)
PPA	:	Power Purchase Agreement
PPP	:	Public Private Partnership
PV	:	Photovoltaic
RUEN	:	Rencana Umum Energi Nasional (National Energy General Plan)
SDG	:	Sustainable Development Goal
SKAT	:	Swiss Center for Technology Management
SNM	:	Strategic Niche Management
VA	:	Volt Ampere

1. Introduction

Indonesia has a severe problem of fossil fuel dependency. The country is one of the world's largest coal producers with 616 million tons of coal production in 2019 (MEMR, 2020). For domestic consumption, coal contributes to around 59%of total energy to generate electricity (IEA, 2021). The excessive consumption of coal for electric power generation has adverse effects on the environment due to carbon dioxide (CO_2) emission (Kurniawan & Managi, 2018). According to BP Global (2019), Indonesia is the 10th largest contributor to global carbon dioxide emissions. However, the President of Indonesia committed to meet the Paris agreement to reduce greenhouse gas emission by 29% on its effort and 41% through international collaboration by 2030 compared to the business as usual (BAU) projection, which is 2869 Mton CO_2 eq (National Energy Council, 2019). Therefore, the government has an immensely ambitious target to increase the renewable energy mix to 23% by 2025 in all sectors (Presidential Regulation No. 22 of 2017).

Many renewable energy sources available domestically in Indonesia can be harnessed to achieve this aspiration, such as solar, wind, biomass, and hydropower. However, in 2020, renewable energy accounted for only around 14.79% of the total 69.67 GW of power generation installed capacity (MEMR, 2020). According to Esti (2021), within the last four years (2016-2020), renewable energy power plants developed only at the rate of 500 MW per year. At this pace, it is projected that the additional capacity of the sustainable energy power plant the capacity of renewable energy power plant will only increase by 2500 MW in 2025. On the other hand, to achieve the 23% target by 2025, Indonesia needs an additional capacity of 9000-10000 MW from renewable energy sources.

Among the renewable energy alternatives, small hydropower has a promising potential to be developed since Indonesia is geographically endowed with many rivers and positioned along the equator line, giving the country abundant rainfall (Erinofiardi et al., 2017). According to National General Energy Plan 2017, Indonesia has a potential capacity of around 19,385 MW of mini and micro hydropower spread across Indonesia's islands (ESDM, 2017).

Unlike large-scale hydro power plants that require an extensive reservoir and large dam construction that are likely to have adverse impacts on the environment in both rivers' upstream and downstream flows, small hydro power is designed as a run-off river system to minimize environmental effects (IRENA, 2015). According to this scheme, the power plant is built in the river's sideway and harnesses slight flow diversion from the river's mainstream to rotate the turbine and flows it back to the river (Paish, 2002). A small weir's construction is sufficient to divert a small portion of the river flow with minimum disturbance to the main river flow (Okot, 2013). If small hydropower is designed and managed properly, dewatering affects the agriculture sector, and decreasing water supply for households located downstream can be minimized (Zhang et al., 2021). Furthermore, a run-off river system reduces the impact on upstream aquatic ecosystems that might be affected by artificial reservoirs in large-scale hydro power plant systems (Comino, 2020; Kaunda, 2012).

Besides considered more sustainable to the environment than large-scale hydropower, small hydropower is also a viable option for rural electrification (Paish, 2002; Okot, 2013; Zhang et al., 2021). Small hydro power has contributed to increased accessibility to electricity in rural areas that lead to the creation of economic opportunities (Okot, 2013; Zhang et al., 2021) and reducing poverty (Kaunda, 2012).

In Indonesia, small hydro power development has gone through a long history. The first small hydro power plant was built in 1880 to supply electricity for tea factories in West Java (Widmer et al., 2001). Later on, by 1925, approximately 400 small hydro power plants had been installed throughout Java island (Widmer et al., 2001). However, most of these power plants have been dismantled along with the abandoned tea industries during World War II (Widmer et al., 2001). Up to now, only a few of the remaining small hydropower is still in operation (Hardjomuljadi & Siswoyo, 2012).

After being neglected for more than 40 years, in the early 1990s a project collaboration between the German and Indonesia government called the Mini Hydro Power Project (MHPP) reintroduced small hydropower technology to Indonesia (MHPP, 2002). This project was intended for technology transfer and competency development (MHPP, 2002). Afterwards, many other international donors and development agencies involved in the development. These projects contributed to providing electricity to remote villages where Indonesia's electrification ratio was still meagre at that time. Furthermore, small hydro power plants have become a clean energy alternative to distributed small-scale diesel generators that are often used as the primary electricity supply in rural areas (MHPP, 2002).

As a promising sustainable energy with many positive impacts, small hydropower has not been developed rapidly. Despite its massive total potential of around 19 GW, only around 2% has been utilized thus far (EBTKE, 2020). Approximately 357 mini and micro hydro power plants have been developed with a total installed capacity of 417 MW (EBTKE, 2020). This figure only makes up to around 0.6% of the total electric power plant installed capacity in Indonesia (MEMR, 2020).

Table 1. 1. Power plant installed capacity in Indonesia (Reprinted from MEMR, 2020; 88)

Power Plant	Capacity (MW)	Power Plant	Capacity (MW)
Steam	34,737.17	Wind	154.31
Combine Cycle	11,669.54	Mini hydro	311.14
Large hydro	5,558.52	Micro hydro	106.37
Gas	5,348.44	Solar	145.81
Diesel	4,779.68	Biogas	112.41
Gas Engine	2,842.03	Waste	15.65
Geothermal	2,130.70	Hybrid	3.58
Biomass	1,763.54	**Total**	**69,678.89**

In Indonesia's electricity sector, fossil fuel power plants have dominated for many decades, particularly coal. By 2019, coal accounted for 59% of the total energy to generate electricity (IEA, 2021). Driven by a vast growing electricity demand, coal is considered an attractive option since Indonesia has an abundance of domestic coal resources that offer low-cost electricity, increase the stability of electricity access and contribute to jobs creation, but accompanied by negative impacts (Kurniawan et al., 2020). While small hydro power is considered as a niche technology where experimentation emerges and develops in the electricity sector in Indonesia. Although it has more advantages in which the resources are available without any significant effort to exploit and not negatively affect the environment, this niche technology struggles to break through the electricity regime.

As part of the sustainable energy niche, small hydropower needs to be further developed to become part of Indonesia's electricity regime or eventually substitute the dominant fossil fuel regime. However, a transition from fossil fuel to sustainable energy is a complex process. Geels et al. (2017) hold that a low-carbon transition to reduce greenhouse gas emissions is a complex multi-dimensional process that requires sociotechnical transformation. They also emphasize that sustainable energy transition cannot be seen as a technological change alone. It also involves transformations in supporting infrastructure, regulations, organization, market preferences, user behaviour and culture. Therefore, further investigation is needed to analyze niche development influenced by the factors that stabilize the regime and landscape development. Besides, a policy framework may also be essential to provide recommendations to facilitate the sustainable energy transition.

1.1. A niche-business model perspective on small hydropower

There are prominent theoretical frameworks that discuss sustainability transition, such as the Multi-Level Perspective (MLP) and Strategic Niche Management (SNM). MLP concept has been developed by Frank Geels and Johan Schot (Geels, 2002; Schot & Geels, 2008). MLP offers a broader analysis level, not only niche development but also analysis in the dynamic interaction between the niche, regime, and landscape level. SNM, first coined by Kemp, R., Schot, J., and Hoogma, R. (1998) and later refined by Raven (2005), has been used to analyze niche experimentations and technological development, particularly in the sustainability transition field (Raven, 2005). Both conceptual frameworks will be reviewed as this is important as a guide for analyzing the case study of small hydropower transition in Indonesia. The MLP is added to SNM to gain insights into the external factors outside the niche, such as landscape factors, socio-technical regime, and how these factors interact (Kamp & Vanheule, 2015; Kamp & Forn, 2016).

Kamp and Vanheule (2015) added insights from the business model literature to SNM. They conclude that an analysis of the appropriate business model is essential for niche growth. In a more recent study, Elmustapha and Hoppe (2020) show that integrating SNM into the business model literature gives more robustness to the business model by addressing a systemic approach while considering broader operational and market challenges. They further suggest that more research still needs to be conducted regarding business models' role in sociotechnical transitions. Sengers et al. (2019) conducted a systematic literature review on experimentation in sustainability transitions. They present a future research agenda on the importance of business management perspectives in the sustainability transition, such as renewable energy. The implementation of business management study is relevant because firms can drive sustainable energy transition through developing business model innovations to benefit from renewable energy markets. Therefore, adding insights from business models frameworks as a complement to SNM and MLP in a sociotechnical transition analysis is a further research area that will be explored in this thesis with an empirical case from a developing country.

1.2. Problem statement

The domination of electricity-based fossil fuel regime may stay stable due to lock-in mechanisms where incumbent energy companies protect their market by maintaining economies of scale utilizing strategies that benefit stakeholders financially and politically (Wainstein & Bumpus, 2016). Meanwhile, sustainable energy technology as niches attempt to challenge the incumbent energy regime, unable to diffuse into a large market at the expected pace. In Indonesia, renewable energy's current contribution to the total energy mix is still far from the target. However, with an enormous energy resource potential and relatively cost-efficient, small hydro power is one of the niche innovations that can be considered to compete regime incumbent.

From a sociotechnical perspective, small hydro power development in Indonesia is a complex process that involves many stakeholders with different interests and values. In this case, sustainability transition frameworks such as MLP and SNM might be perceived as appropriate approaches that can be utilized to analyze this particular case. Nevertheless, as Wainstein & Bumpus (2016) mentioned, business model innovations also have an essential role in driving the commercialization of sustainable energy business and accelerating the green energy transition.

Besides the dynamics that go along with small hydro power technology development and the influencing sociotechnical aspects, several business models have been used in the Indonesian small hydro power sector. The small hydro power market niche actors such as Independent Power Producers (IPPs), international donors, development agencies, cooperatives and NGOs may have different business models that could have various outcomes. Therefore, it is necessary to systematically address the sociotechnical aspects of the small hydro power niche development using the MLP and the SNM framework while at the same time investigate the role of business models to increase the adoption of small hydropower in Indonesia’s electricity sector.

1.3. Research questions

The main research question is:

"How has the small hydro power market niche developed in Indonesia and how did business models facilitate niche development?"

The following sub questions will help as a guide to answering the main research question:

1. What are the main actors and factors that have influenced small hydro power niche development?
2. What are the barriers and opportunities with regard to small hydropower implementation in Indonesia?
3. How have current business models influenced small hydro power niche development in Indonesia?
4. How can small hydro power initiatives be stimulated?

1.4. Report structure

This thesis contains eight chapters. The background of this study, knowledge gap, research objectives, and research questions have been explained in this chapter. In the next chapter, theoretical frameworks used in this thesis are described and followed by how these frameworks are integrated and conceptualized in an analytical framework. Chapter 3 explains the research approach and methodology used in this thesis to answer the research questions.

In chapter 4, first, the technology description of small hydropower will be explained in brief to guide the reader to comprehend the development of small hydropower in Indonesia. Second, the historical development of small hydropower in Indonesia is depicted. Third, a stakeholder map is elaborated to inform the Indonesian electricity sector structure, renewable energy policymaking, and stakeholders' roles and responsibilities. Finally, the essential formal institutions as guidance for the electricity sector and renewable energy development is explained.

In chapter 5, landscape and regime factors that have influenced the development of small hydro power in Indonesia will be analyzed. Chapter 6 will analyze niche development using the SNM framework and followed by analysis of barriers and opportunities in small hydro power sector in Indonesia. Business models of small hydropower in Indonesia will be elaborated in chapter 7. Chapter 8 discusses the findings, academic contributions, practical contribution, limitation of the study and further research. Finally, chapter 9 summarizes this thesis by answering the research questions and offering recommendations. Figure 1.1 shows the report structure as reading guide for this thesis.

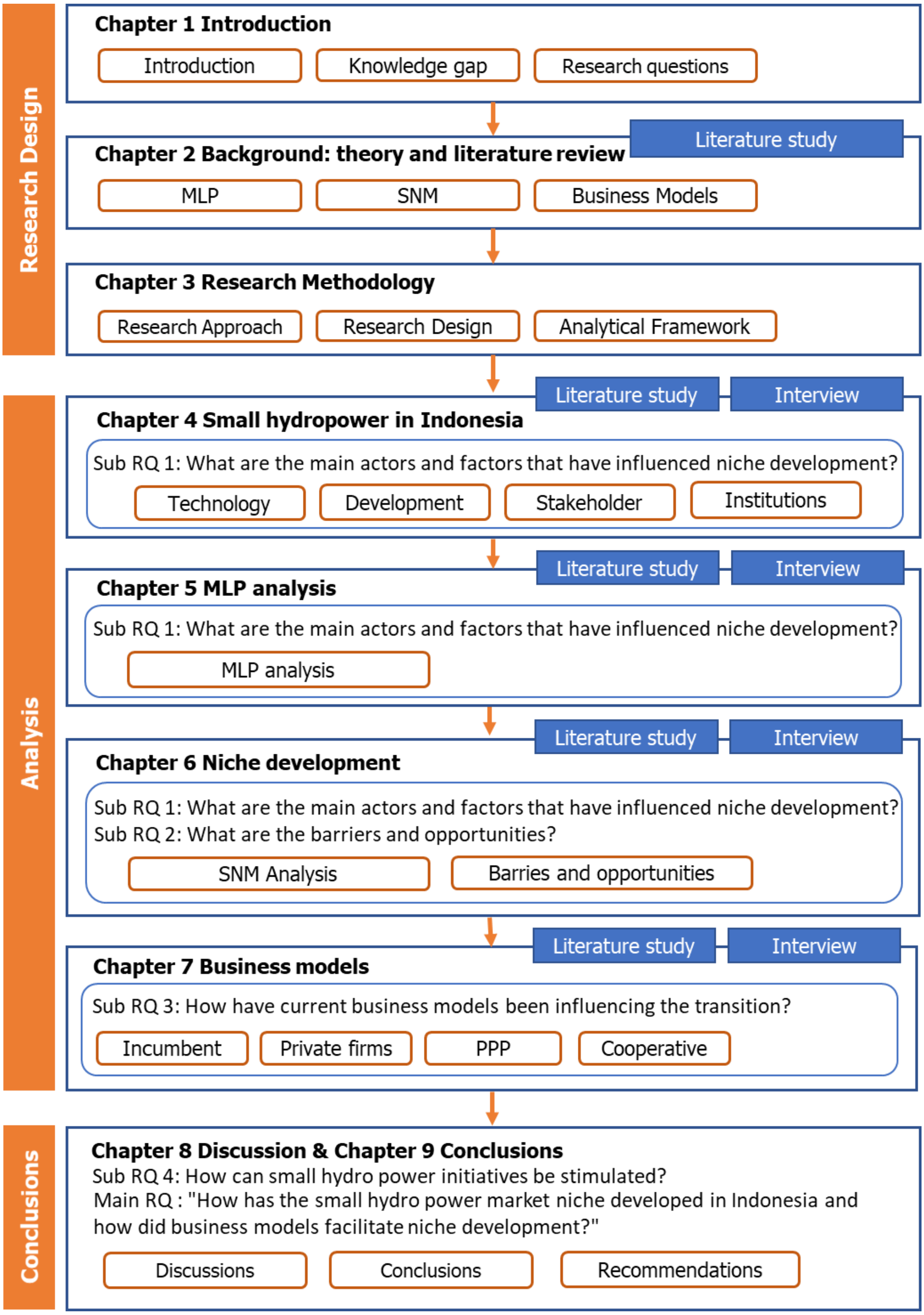

Figure 1. 1. Report structure

2. Background: theory and literature review

Fossil energy is currently proving difficult to replace since the fossil energy systems are stabilized through a lock-in mechanism in the regime dimensions (Geels, 2011). With abundant renewable energy sources that are more environmentally friendly and relatively technologically well-developed, sustainable energy should have many opportunities to substitute fossil energy. Nevertheless, relying only on the technology's superiority is not sufficient to drive the transition (Geels et al., 2017). Sociotechnical and business aspects also need to be considered when analyzing sustainable energy transition processes (Elmustapha & Hoppe, 2020). To understand the transition process, scholars have developed theoretical frameworks related to sustainability transition. Therefore, in this chapter, several theoretical frameworks, including MLP, SNM and those about business models, will be presented to guide analysis in the present study. In addition, technological aspects of small hydropower will be addressed in a technology map as it becomes the basis for further discussion regarding the technical aspects.

2.1. Multi-Level Perspective

The sustainable energy transition is a complicated process since it involves technological change (i.e., the substitution of fossil fuel with renewable energy) and social changes such as culture, market preferences, regulations, institutions, and governance system (van Eijck & Romijn, 2008). Although the new sustainable technology is reliable and offers future benefits for the environment and society, there is no guarantee for successful adoption because the existing regime resist the change and reinforce its stability through lock-in mechanism (Geels, 2012). Lock-in mechanism occurs in various regime dimension such as sunk investment in infrastructure, user lifestyles, consumer preferences and vested interest of regime actors (Geels, 2012).

Geels (2004) explains that sociotechnical transitions emerge from the dynamic interaction of three different levels: macro-level (landscape), meso-level (regime), and micro-level (niche). A transition will occur when the interaction between three levels is interrelated and reinforced, as shown in Figure 1.1 (Geels, 2002, Geels, 2004; Loorbach, Frantzeskaki, & Avelino, 2017).

At the macro-level, landscape change(s) put pressure on sociotechnical transition. The pressure can be a gradual development of global climate change issues, slow culture adjustment, and sudden shocks such as the global economic crisis, pandemics, wars, and natural disasters.

The regime concept is a core in the transition theory, where sociotechnical changes occur (Loorbach et al., 2017). The regime is an established system maintained by the related actors to continue sustaining its dominance and stability in economic, institutional, organizational, and cultural (Geels, 2004).

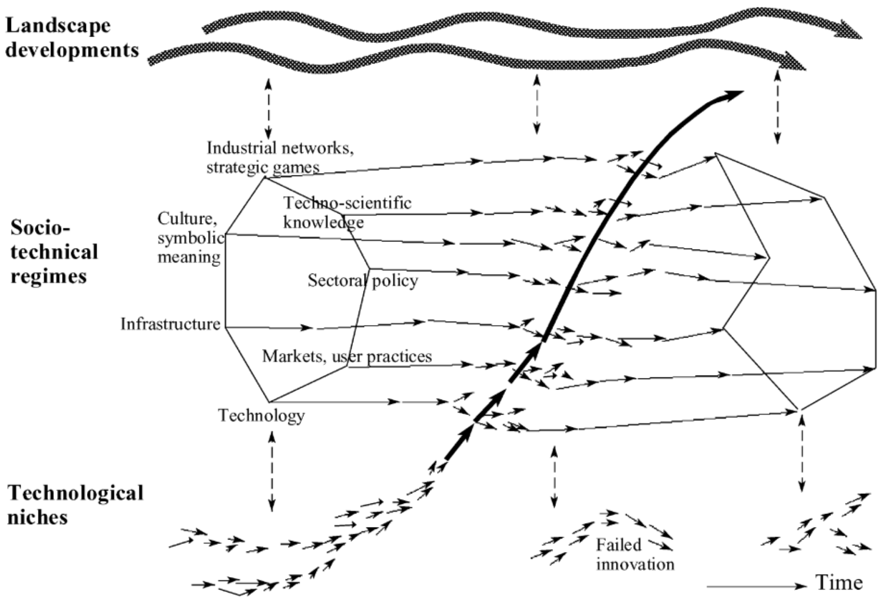

Figure 2. 1. Dynamic interaction of different level in the transition process (Geels, 2002; 1263)

A niche refers to a protected space for innovative projects where the actors such as entrepreneurs and startups introduce and experiment with new sustainable technology to replace regimes in which supports such as subsidies and incentives are required (Geels, 2011; Schot & Geels, 2008).

The MLP has been developed for more than fifteen years through many debates based on various case studies that contribute to new insights and criticism to this framework (Geels, 2019). Reflecting on the results of the case studies, criticism and insight from broader social sciences, Geels (2019) elaborated seven concepts related to (1) the resistant of the incumbent firm and reorientation, (2) politics and power, (3) multiple transition pathways, (4) grassroots innovation, (5) policy analysis, (6) cultural discourse and framing struggles, (7) destabilization and decline. Some of these concepts (incumbent resistant, politics and power, and grassroots innovation) that might be relevant to guide the analysis in this thesis will be summarized below.

The incumbent company in the fossil fuel regime is often described as maintaining lock-in condition and resisting fundamental changes in existing regime norms to appropriate profit for their business and the related stakeholders (Geels, 2014). Incumbent firms use various ways to maintain regime stability and resist sustainability transition, including framing strategies, lobbying strategies and confrontational strategies by using the impact of plants closure and layoff as means of their agency (Geels, 2019). Furthermore, a group of incumbent actors (industries, political parties, expert, media) likely to have greater access to policymakers to adhere to the established policy and maintain regime stabilization. Geels (2019) emphasizes that political struggles between various actors and alteration of the power balance between different groups of actors influence a significant policy change. However, Geels (2019) argues that the incumbent firms might consider reorienting toward sustainable innovation rather than resist the changes if they see economic opportunities.

Besides the mainstream business in sustainable green innovation, grassroots innovation driven by activists or community actions emerge to offer an alternative way to sustainable development by using green technology and emphasizing social innovation (Seyfang & Smith, 2007). Despite a massive movement and the positive impacts in addressing local community problems, grassroots innovation faces internal and external challenges (Geels, 2019). Internally, they likely depend on key activists. However, this dependency becomes problematic when these key persons leave the organization. The learning process and knowledge are often not appropriately managed. They also do not aim to grow and scale up innovations. Externally, existing laws and regulations at the regime level often act as barriers to grassroots innovations. Also, the radical innovation they offer tends to limit access to funding sources and lower the wider public's resonance (Geels, 2019).

2.2. Strategic Niche Management

Strategic Niche Management (SNM) is a framework that can be used for analyzing sociotechnical transition and providing policy recommendations (Raven, 2005). SNM suggests that experimentation at the local level can be simultaneously and coherently analyzed from both technical and social sides. It serves as an analytical tool for the research related to introducing new technology that promises a more sustainable future (Hoogma et al., 2002; van Eijck & Romijn, 2008). However, replacing an established regime technology is challenging because the regime is stabilized through a lock-in mechanism in regime dimensions such as industry, market preference, policy, and culture (Geels, 2011). Therefore, SNM suggests that the niche plays a crucial role as the starting point of the transition process (Geels, 2011; Schot & Geels, 2008).

A niche technology often encounters highly uncertain aspects of design, user preferences, public policies and social-network (Geels, 2004). On the other hand, the regime has more stable rules that might outmatch the niche in terms of technologically and economically in the early stages. Hence, the SNM suggest the concept of a technological niche as a protected space for nurturing and developing new radical technology (Kamp & Vanheule, 2015). Smith and Raven (2012) argue that niche protection consists of three functional properties: i.e., shielding, nurturing, and empowering. In the present study, SNM will be explained along with these three functional properties.

2.2.1 Shielding

Many historical case studies on transition show that niches on sustainable innovation struggle against the pressure from multiple dimensions of the regime such as technology, industry, user, market, culture, and policy (Geels, 2011). A niche as a protected space is required to guard innovation against multiple regime pressures (Smith & Raven, 2012). Furthermore, Smith and Raven (2012) define shielding as the process of guarding of an emerging innovation. They divide this process into passive and active shielding. Passive shielding implies the protection process where the innovator experiment with the technology in different geographical locations away from the regime's operation areas until it becomes economically feasible and is adopted by a small number of users (i.e., in an emerging market niche).

Smith and Raven (2012) further explain that active shielding encompasses the protection process that entails deliberate interventions and strategies from actors. Active shielding from policy actors can be regulations on subsidies, incentives, and tariffs to stimulate the supply side. Policy actors can implement strategies to change user preferences on the demand side, such as information campaign, quotas, and market segmentation. A non-policy actor (i.e., a private company) utilizes active shielding by establishing a business unit that performs as an incubator to develop new radical innovations apart from the mainstream organization.

2.2.2 Nurturing

The nurturing processes in the SNM framework consist of three main activities: voicing and shaping expectations, learning processes, and network formation (Smith & Raven, 2012). A niche is designed to support these three niche activities in a cycle that create a reinforcing mechanism between each process. In the following part, each process will be elaborated and followed by explaining the dynamic interaction between each activity that influence niche development.

Voicing and shaping expectations

According to Raven (2005), expectations regarding new technology's future are essential for firms to decide to invest in R&D of the technology. Promises about new technology's potential to become future standard and a dominant design also encourage users to adopt the technology. However, initially, actors may not have the same expectations that will lead to different technological trajectories. Furthermore, Kamp and Vanheule (2015) add that expectations can shape the design of the technology and attract new actors to provide resources for technology development. Hoogma et al. (2002) argue that positive expectations shared among actors in the early stages of a niche tehcnology development are crucial to strengthening their confidence in the technology's future benefit since it has not yet been proven.

As an additional analysis of expectation in the existing SNM framework that refers to the internal expectation of actors within the niche, Kamp and Vanheule (2015) suggest external expectation that is defined as awareness of actors outside the niche regarding the development of the technology and whether they have negative or positive expectations.

Network formation

Actors related to the niche's development, such as producers, suppliers, researchers, customers, and regulators, are dynamically linked together in the network carrying the expectations and sustaining niche development (Raven, 2005). Further, Raven (2005) explains that two important network characteristics influence niche development. First, the outcome of niche development is strongly affected by network composition. The actor-network may consist of regime actors who will try to support the incumbent technology and harness their resources to maintain it as a dominant design. Such actors often large firms that may prevent a niche from developing and introducing radical innovation. These firms will retain domination through incremental innovation of their technology. On the contrary, actors with no strong ties with the regime, such as non-users, researchers, and other industrial sectors, may promote radical innovation and support niche development. Hence, Kamp and Vanheule (2015) argue that heterogeneous actors in the network which bring different interests and roles create a complete network composition.

Second, Raven (2005) argues that the alignment of actors' expectations, strategies, and activities influences niche development. Firms that introduce new radical technology carry different expectations regarding technology trajectory from the large firms that reap economic benefit from the incumbent technology. The alignment can be strengthened when the relationships between actors are maintained through formal cooperation.

Learning processes

SNM puts learning as a vital issue in which actors learn from the outcome of technology experimentation in society and later improve the technology's sociotechnical configuration (Raven, 2005). The learning process involves interaction between actors in many niche experiments that will increase the knowledge about the technology and its social aspects.

Hoogma et al. (2002) distinguish five aspects of learning related to niche technology experimentation in society. The five aspects concern learning of technical development and infrastructure, environmental and societal impact, user context development, government policy and regulations, and industrial development. Furthermore, Schot and Geels (2008) add learning about cultural and symbolic meaning in their list of multiple learning dimensions. In the case study of the small wind turbine in Kenya by Kamp and Vanheule (2015), two more aspects of learning are added. First, the analysis of wind energy potential, and the second, learning about the appropriate business model to gain mass-market adoption.

According to Kamp et al. (2004), learning can be categorized into four types: learning by searching, learning by using, learning by doing, and learning by interacting. *Learning by searching* focuses on knowledge development activities by research and development actors in the universities, firms' R&D department, and government research organizations. *Learning by doing* is to understand better how to produce technology and gain experiences from problem-solving during the manufacturing stage. *Learning by using* involves the end users of the technology in which they learn about the technology's characteristics. The optimal performance characteristic of the product can be evaluated through interaction between users and technology. *Learning by interacting* takes place during communication between producers, users and other actors in innovation system.

2.2.3 Empowerment

After being nurtured, niche innovation might increase its competitiveness. In this stage, shielding activities can be eliminated from niche innovation, and the increasing ability to compete with the regime can be empowered to penetrate the larger market (Smith & Raven, 2012). Therefore, the regime challenges the pressures from the exogenous landscape development and simultaneously from niche innovation when it becomes more competitive (Turnheim & Geels, 2019). Depending on how the mainstream selection environments are influenced by niche innovation, Smith and Raven (2012) distinguish the empowerment of niche innovation into (1) fit and conform empowerment, (2) stretch and transform empowerment.

In fit and conform empowerment, niche innovations break into the regime level without changing the regime's selection environments. Thus, only incremental improvement occurs in the broader sociotechnical aspects rather than disruptive innovations (Smith & Raven, 2012). Fit and conform can be fairly dis-empowering for sustainable niche innovation because it conforms to the regime's selection environment, such as alignment with the existing industrial structures and norms.

Stretch and conform empowerment implies that the regime's selection environments (e.g., regulations, laws and incentives) need to be altered to support the diffusion of niche innovations, which requires empowerment activities such as creating coalitions, lobbying and framing (Turnheim & Geels, 2019).

2.3. The SNM framework for sustainable energy in developing countries

SNM has been more increasingly used to analyze sociotechnical transition in developed countries (Wieczorek, 2018). Since sustainability has also become crucial in the developing world, scholars began to apply this framework to analyze sustainability transition in developing countries. Hence, the literature search was conducted to get valuable input for this thesis on how the SNM framework has been used in the case study for sustainable energy transition analysis in developing countries.

Since this literature review focuses on the use of SNM to analyze sustainable energy transition in developing countries, the keywords used in google scholar are using a combination of "strategic niche management" AND "sustainable energy" AND "developing country". Around 220 articles were yielded from the first round. The principal investigator selected manually from the list in the next round since the result also shows papers that are not discussing case studies in developing countries. Finally, it was further refined to ten relevant papers representing the discussion on SNM framework development for renewable energy in developing countries, as shown in Table 2.1. Many other papers may not be included in this list. However, the ten selected papers in the list are perceived as sufficient to show how the SNM framework has been used to investigate sociotechnical transition in developing countries' sustainable energy field.

In general, each piece of the literature on different niche technology cases from various locations will explain the fundamental concepts of SNM at the beginning of the journal paper that is quite similar between them. However, more attention is geared toward framework development, knowledge gaps, scientific contributions, managerial implications, and further research opportunity.

Table 2. 1. Overview of ten selected papers on SNM for renewable energy in developing countries

Authors, year	**Energy, Country**	**Research design**	**Findings**
Van Eijck & Romijn, 2008	Jatropha biofuel in Tanzania	Case study on seventeen jatropha development projects by various actors involved.	Introduction of production chain concept for SNM framework to guide the analysis of multi-regime dynamic related to the niche.
Romijn, Raven & Visser, 2010	Biomass in India	Case study on four biomass energy projects.	Application of SNM in the context of developing countries with considering additional factors from the learning-based approach such as local institutions, culture, community development, and capacity building.
Verbong, Christiaens, Raven & Balkema, 2010	Biomass gasification in India	Case study of biomass gasification experimentation over the last 30 years.	Different from what has been argued by many SNM case studies, regime instability does not create window opportunities but becomes a barrier for large-scale niche diffusion. Different niche strategies are required to overcome barriers.
Drinkwaard, Kirkels & Romijn, 2010	Micro-hydropower in Bolivia	Case study of eight micro-hydropower projects limited to stand-alone systems.	A learning-based approach is used to analyze other barriers rather than technology, finance, and management. These barriers include local communities' involvement, transfer of knowledge, capability building, and continuous improvement through learning.
Kamp & Vanheule, 2015	A small wind turbine in Kenya	A literature study, field study, and participatory observation method were used as the case study materials.	Integration of SNM with Multi-Level Perspective adds insight into the effect of socio-cultural factors on niche development in the context of a developing country. Analysis of the appropriate business model is essential for niche growth.
Kamp & Forn, 2016	biogas sector in Ethiopia	A case study on domestic biogas in Ethiopia.	Barrier analysis using SNM and MLP.

Elmustapha, Hoppe & Bressers, 2018	Solar PV and solar thermal in Lebanon	Two case studies that compare two renewable energy technologies (i.e., solar PV and solar thermal.	SNM used for a comparative study between two niches. Specific SNM factors might differ from developed countries, such as cultural, institutional, and economic factors.
Fatimah (2020)	Jatropha development in Indonesia	A case study in Grobogan district	Combination of functions of the innovation system and SNM
Mirzania, Balta-Ozkan & Marais, 2020	Solar Power in the US and South Africa	Two case studies aim to compare the case in a developed and developing country	By comparing two cases using SNM factors, replicable success factors from a developed country are identified.
Elmustapha & Hoppe, 2020	Solar PV in Lebanon	A case study using SNM as complementary theoretical framework for business models.	SNM insights complement the business model framework to overcome challenges in the sustainable energy transition, such as institutional and financial issues.

Based on these studies and publications, researchers have devoted effort to finding the knowledge gaps and improving the SNM framework. The production chain concept to better guide the SNM analysis was introduced by Van Eijck and Romijn (2008). Another sustainability transition framework, MLP, was added in the study by Kamp and Vanheule (2015) and Kamp and Forn (2016) as a complementary framework to the SNM framework. Other researchers, Romijn et al. (2010) and Drinkwaard et al. (2010), combined the learning-based approach to gain more robustness of the SNM framework for developing countries. They included particular factors, such as local institutions, culture, community development, and capacity building. However, the SNM framework can hardly be found used to analyze niche development in Indonesia. Only an article by Fatimah (2020) uses Technological Innovation Systems (TIS) as the main framework to analyze Jatropha development in Indonesia with complementary insight from SNM.

There are frequent topics discussed in niche development in developing countries from ten selected papers: knowledge, financial, infrastructure, and policy. Lack of knowledge that hindered niche development has been mentioned by Romijn et al. (2010), Kamp and Forn (2016), Kamp and Vanheule (2015). In addition, Mirzania et al. (2020) revealed that a lack of knowledge sharing was conducted by actors in developing Concentrated Solar Power (CSP) in South Africa. Financial barrier is the most common topic discussed in the ten selected papers. It indicates that the financial barrier is a frequent barrier faced by developing countries.

Regarding the infrastructure barrier, Van Eijck and Romijn (2008) mentioned that the infrastructure weakness of the electricity regime in Tanzania could be an advantage for the Jatropha niche as it can be developed as a decentralized energy source. On the other hand, Kamp and Vanheule (2015) argued that underdeveloped Kenya's infrastructure increases the product price since small wind turbines have to be distributed to remote areas. Policy related barrier is also a prominent discussion in developing countries. For example, Mirzania et al. (2020) addressed the lack of consistent policy support for CSP development in South Africa. Elmustapha et al. (2018) mentioned that subsidized electricity tariffs make solar technology in Lebanon uncompetitive.

Although Smith and Raven (2012) have proposed a refined SNM framework, the selected articles published after 2012 still did not analyze their niche development by using three properties of niche: shielding, nurturing and empowerment. Most of these papers use the traditional SNM framework that only analyzes niche nurturing: network formation, shaping expectation and learning. Elmustapha and Hoppe (2020) discussed the active shielding approach in addressing financial strategies of Solar PV development in Lebanon.

The business model's insights have been added to the SNM study by Kamp and Vanheule (2015). In a more recent study, Elmustapha and Hoppe (2020) focused on how business models can overcome sustainable energy transition challenges in developing countries, such as financial, knowledge transfer, and social challenges. In their case study on solar energy niche development in Lebanon, different business models are analyzed with complementary insight from SNM. The results reveal that a specific business model implemented for niche market development relates to the increasing one or more activities in the niche level (i.e., shaping and voicing expectations, network formation, and the learning process).

2.4. Small hydro sociotechnical transition research in the global south

To identify articles on small hydro power in Indonesia, the principal investigator use search terms in Scopus within three fields (i.e., title, abstract and keywords): "micro hydro" or "mini hydro" or "small hydro" and set Indonesia as the limit. In total, the search process generated 167 articles. In general, most articles discuss micro hydro power potential study for a specific location or region, engineering and turbine design, feasibility study, sustainability assessment and comparative study. However, some articles are relevant to sociotechnical discussion of this thesis. For example, Didik et al. (2018) investigate sustainability issues of micro-hydropower implementation in Indonesia. They reviewed previous papers on micro-hydropower sustainability in Indonesia and conducted field observation and interview in their study. They showed that sustainability is related to many aspects, such as the environmental impact, economic, technical design, and human resources' ability to ensure the power plant's operation in the long term. In addition, a case study conducted by Sato et al. (2018) analyzed micro-hydropower in Ciptagelar Village, West Java, Indonesia, that emphasizes economic sustainability for the local community through collaboration with a private company. However, there is no research has been conducted to analyze comprehensive sociotechnical aspects and provide policy recommendations for small hydro power development in Indonesia.

The subsequent search round was focused on articles from the Global South. In this round, the focus was directed toward articles related to sustainability and transition. Therefore the search terms used: "micro hydro" or "mini hydro" or "small hydro" and “transition” or “sustainability”. By limiting countries from the global south, it generated 92 documents. The result shows that various subjects discussed related to small hydro power such as engineering, environment, sustainability assessment, business and social.

Regarding sustainability assesment, López-González et al. (2019) assessed the long-term performance of six micro hydro power plants in Venezuela that have been operated between 20 and 60 years. Similarly, Zhang et al. (2021) present massive development of small hydropower in China that creates sustainability issues on the environment. It causes serious rivers' dewatering, water access problems, and ecological impacts. Culaba and Marfori (2020) investigate micro hydro power development for rural electrification in the Philippines through a case study that shows its implementation problems and challenges. These articles represent studies that predominantly focussed on sustainability issues of small hydro power in developing countries.

Jenkins and Sovacool (2018) showed the distribution of 24 SNM papers by the technology between 2002 and 2016 but did not include small hydro power in the list. However, in section 2.3, we show that only one article by Drinkwaard et al. (2010) used the SNM framework to analyze Bolivia's micro hydro power niche development. In their study, the SNM framework is supplemented with Douthwaite's learning-based approach for analyzing barriers of micro hydro power in Bolivia. Furthermore, Jenkins and Sovacool (2018) argued that SNM is predominantly used to analyze niches in the UK and the Netherlands. They showed that only a few SNM studies use case studies from the country in the Global South.

2.5. Business models frameworks

Osterwalder et al. (2005) define business model as a conceptual tool to explain how a company runs a business in terms of how to deliver the products and services value to the customers using the company resources (i.e., employee, infrastructure, network, and financial) to generate sustainable revenue and profit. Zott and Amit (2010) have a similar perspective on how the company organized its business activities to create value for all parties. Teece (2010) viewed a business model as a mechanism for creating value to meet the customer need and generate profit. Osterwalder and Pigneur (2010) list nine building blocks in a more practical framework that forms four key areas: the product, the customer, infrastructure management, and the financial aspect. In Figure 2.2, nine building blocks are mapped in the business model canvas to guide users to design a business model and understand how they organize it. The description of nine component of the business model canvas is described in Table 2.2.

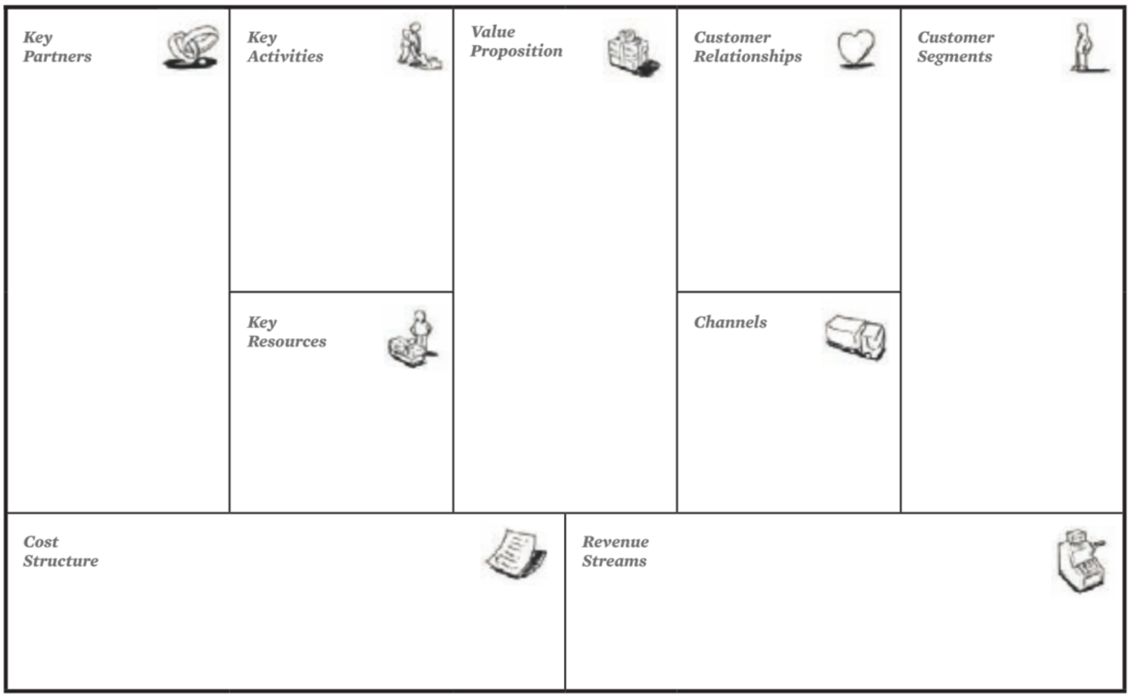

Figure 2. 2. Business model canvas, adapted from Osterwalder and Pigneur (2010)

Table 2. 2. Description of the component of business model canvas (Osterwalder and Pigneur, 2010)

Component	Description
Value proposition	The value proposition describes what product or service that company offers to fulfil customers needs and solve customers' problems
Customer segments	The different segments are defined based on characteristics such as needs, behaviours, or other attributes.
Distribution channels	Describe the ways a company deliver its products or services to customers.
Customer relationships	This building block describes how a firm establishes and maintains a relationship with customers.
Revenue streams	The ways a firm generate income are explained in the revenue stream building block.
Key activities	The essential things a company has to do to make the business model operating.
Key resources	Key resources including people, financial or materials that are required to carry out key activities
Key partnerships	Describes a network of partners and suppliers along the value chain required to support the business.
Cost structure	All costs incurred from a firm’s business activities.

2.6. Business models in sociotechnical transition

From the sustainability transition perspective, consensus has reached in that business models have a crucial role in creating disruptive changes in society by supporting new technology diffusion into the market (Bidmon & Knab, 2018). Furthermore, Bidmon and Knab (2018) emphasize that technological innovation alone is insufficient to create systemic changes; a non-technological factor such as business model innovation is needed to shift the current consumption and production pattern. Business model innovation can also be used as a tool to overcome the barriers of new clean technology diffusion (Boons & Lüdeke-Freund, 2013). In a similar vein, Wainstein & Bumpus (2016) mentioned that business model innovations also have an essential role in driving the commercialization of sustainable energy business and accelerating the green energy transition.

According to Bidmon and Knab (2018), business models have three roles in sociotechnical transitions. First, the business model acts as a dominant industry recipe in the sociotechnical regime and reinforces the regime's dynamic stability. Regime actors use existing business models of the dominant technology and regime dimensions to exert pressure on niche innovation to grow and create barriers to sociotechnical transition. Second, in order to commercialize a new technological innovation, business models are required. However, Bidmon and Knab (2018) argue that this role can be either as a new business model coupled with new technological innovation or utilizing existing business models at the regime level to commercialize the technology. Finally, business models can be considered as niche innovation apart from technological innovation. In this role, business models are also influenced by selection pressure from the sociotechnical regime and landscape development. A new industrial recipe will be created if the new business model innovation succeeds to break through into the regime level.

2.7. Knowledge gap

Huijben and Verbong (2013) have started to combine sustainability transition and business model approach in analyzing the PV niche business model in Netherland. In a more recent study, Bidmon and Knab (2018) refined the MLP framework by involving the business model's concept into the dynamic interaction of different transition process levels.

In a recent study, Elmustapha and Hoppe (2020) show that integrating SNM into the business model literature gives more robustness to the business model by considering broader operational and market challenges. They further suggest that more research needs to be conducted regarding business model's role in sociotechnical transition. Sengers et al. (2019) conducted a systematic literature review on experimentation in the sustainability transition. They highlight a future research agenda on the importance of business management perspectives in the sustainability transition, such as renewable energy. The implementation of a business management study is relevant because firms can drive sustainable energy transition through developing business model innovations to benefit from renewable energy markets. Considering the research gap where the role of business models in sociotechnical transition remains underexplored, the additional insight from sustainable energy transition in a developing country is expected to bridge this gap. Therefore, this thesis present analysis on small hydro power niche in Indonesia as an empirical case from a developing country by using SNM with complementary insights from MLP and business models.

Jenkins and Sovacool (2018) showed that case studies using SNM are not well distributed geographically and relatively limited for global application. Only a few SNM studies using the case from the country in the Global South compared to the Global North. On the other hand, countries in the Global South may face specific circumstances and challenges in their effort toward low-carbon transition (Goldthau et al., 2020). Therefore, it is necessary to fill the gap in sustainability transitions research by offering the global south perspective.

3. Research methodology

This chapter describes the research design and methodology that will be used in the present study to assess small hydro power niche market development in Indonesia. This study combines explanatory research and exploratory research. The explanatory research describes and assesses niche internal processes and dynamic interactions with regime and landscape factors. Besides, this thesis will gather insight from interviews with actors regarding their expectations through an exploratory approach.

Sekaran & Bougie (2016) indicate that exploratory research often depends on qualitative approaches to collect the data, such as interviews, focus group discussions, informal discussions, and case studies. As part of the qualitative research approach, the case study is perceived as an appropriate research strategy for this thesis. Therefore, this thesis uses a case study to present various small hydropower business models' that are currently implemented in West Java.

3.1. Geographical boundary

The phenomena investigated in this study are the development of small hydropower in Indonesia within the context of energy transition and the emergence of various business models implemented by the incumbent company and niche actors. Inhabited by more than 270 million people, Indonesia ranks fourth among the the world population (World Population Review, 2021). With the current average population growth rate of 1.49% per year, it is predicted that in 2069 the population will increase to more than 337 million people. Indonesia's GDP is ranked sixteenth in the world, with a projected growth of around 4.8% by 2020 (The World Bank, 2020). Over the last decades, Indonesia's rapid economic development and increasing population have created significant electricity demand. McNeil et al. (2019) projected demand for electricity in Indonesia is projected to increase three times in the next 20 years. The large population coupled with economic growth may become problematic for environmental and global sustainable development. More particularly, Indonesia's challenge in reducing its carbon footprint by targeting the higher renewable energy contribution in the electricity sector by 2025.

Indonesia is therefore considered a promising case study of energy transition in a developing country context. Considering that Indonesia is a large archipelago consisting of 17,000 islands with diverse culture, appropriate case study selection within the context should be determined. Furthermore, within the limit of research duration, this thesis limit the case study to a geographical boundary. Therefore, West Java Province is selected as the geographical boundary for the case study because it has more small-hydropower plants than other provinces in Indonesia. From the total 357 mini and micro hydro power plants installed throughout Indonesia, West Java contributes to 72 micro-hydro and 39 mini-hydro power plants, comprising 31% of the total mini and micro hydropower in Indonesia (DESDM Jawa Barat, 2019). Although the province has relatively lower small-hydro potential than other provinces, the small hydropower development is significant in West Java.

With a large number of plants installed in West Java, diverse business models are implemented. Several business entities have been involved in the development of small hydropower in this province. The state-owned electricity company (PLN) operates several hydropower plants ranging from the large scale utilizing big reservoirs in Saguling and Cirata to micro hydropower plants. In addition to the existing regime, some niche actors are involved in the small hydropower development in West Java. Rural cooperatives, private firms, and regional government-owned enterprises (BUMD) operate small hydropower plants with various business models.

3.2. Case study design

The unit of analysis of this study is small hydro power in Indonesia. According to Paish (2002), small hydro power refers to a capacity below 10 MW. The analysis of this sustainable energy innovation focuses on **the period between 1990 and 2021**. Although small hydropower was first introduced in1900s, it was neglected for years after World War II (Widmer et al., 2001). A significant milestone was made in early 1990 when international donors re-introduced small hydropower in Indonesia (MHPP, 2002). Following the introduction phase, this study aims to analyze the niche development and transition dynamic following the emergence of various small hydropower business models that face the challenges from multiple regime dimensions and interaction with landscape development that create windows of opportunity for small hydropower.

For the business model case study, the sampling method used is judgement sampling. According to Sekaran and Bougie (2016), judgement sampling is often used when only a limited number of people have the required information. Besides, judgement sampling is often used because the interviewee is conveniently available to the researchers. Currently, several private firms and cooperatives are operating small hydropower business. Nevertheless, due to the accessibility to reach the interviewee representing private firms and cooperatives, the principal investigator selects the conveniently available interviewees.

As a state-owned electricity company, PLN aims to profit from the electricity business while providing electricity access for all people. The private sector participates in the electricity generation business since the government create supportive conditions for private investment. Four private firms PT Petro Hidro Optima, PT Energi Andalas Group, PT Kerinci Merangin Hidro, PT Bumiyasa Indonesia Energi represent the case study for private firms PPA business model. The four private companies operate mini-hydro power in West Java province. In addition, this thesis will show the Public-Private Partnership (PPP) business model, defined as the partnership between public and private sectors. The PPP will be investigated using the case study of PLTMH Cinta Mekar in West Java, which is commonly called by Pro-Poor Public-Private Partnership (5PS). Finally, the cooperative business model will be investigated using the case study of Cooperative Rimba Lestari in West Java.

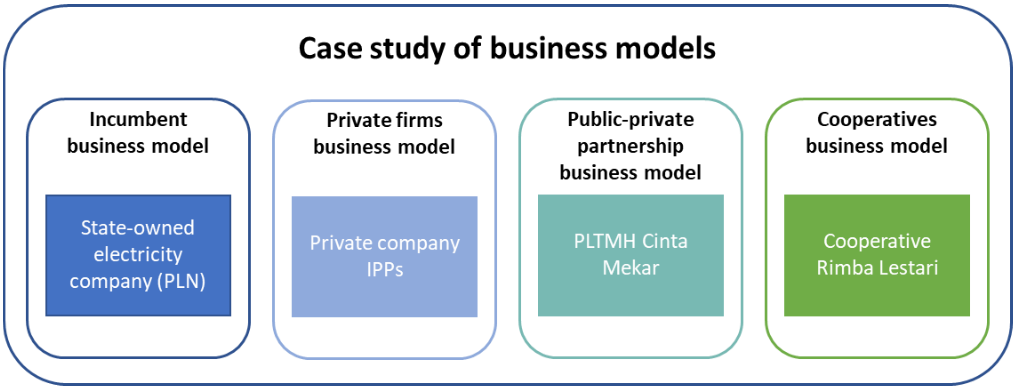

Figure 3. 1. Case study selection of small hydropower business models

3.3. Research flow

This section describes the research flow and method used to answer the research questions. In general, this thesis is divided into three parts: research design, analysis and conclusions, as shown in Figure 1.1. The research design consists of three chapters. Previously in the first chapter, this study's background and problem statement have been elaborated, followed by the knowledge gap and research questions. The second chapter describes conceptual frameworks (MLP, SNM and business models) used in this thesis based on a literature study. The third chapter elaborates research methodology comprising the research approach, research design and analytical framework from the integration of three conceptual frameworks.

In the analysis part, sub-research questions are answered by using analysis on both literature study and interviews. Information collected from answering sub-research questions then used to answer the main research questions. The rationale and objective of each sub-research questions are delineated as follows:

1. What are the main actors and factors that have influenced small hydro power niche development? Small hydropower development in Indonesia is inherently related to a complex system on the broader electricity system. Many stakeholders are involved in the governance, policymaking, business and implementation of small hydropower. This sub-question aims to identify stakeholders involved, policy and regulations, surrounding infrastructure and informal institutions. First, the historical development of small hydropower in Indonesia is depicted, followed by a technology map that is useful to explore the value chain. Second, identification of involved actors can be drawn in an actor map which can be used to explain stakeholders' interests, roles, authority and interdependence between actors (Enserink et al., 2010). Therefore, a stakeholder map is provided and detailed to inform the Indonesia electricity sector structure, renewable energy policymaking, and stakeholders' roles and responsibilities. The SNM framework is applied to investigate internal niche activities during the development of small hydropower in Indonesia. Third, the main factors

will be answered by integrating SNM and MLP framework to reconstruct niche development and analyze landscape factors that create pressure on the regime and open a window of opportunities for the small hydro power niche. The analysis will be conducted from the 1990s until the present.

2. How have current business models been influencing the small hydropower transition in Indonesia?
   Since the introduction of small hydropower in Indonesia in the early '90s by international donors and development agencies, various business models that have been implemented may have different challenges. The second sub-question will investigate the diversity of business models in small hydropower and present the detailed business models for each niche actors using nine building blocks of business model canvas developed by Osterwalder and Pigneur (2010).

3. What are the barriers and opportunities of large scale implementation of small hydropower in Indonesia?
   The current structure of the electricity sector in Indonesia may influence niche development. Other factors such as technology, infrastructure, formal institutional aspects, and culture can create low carbon transition barriers in Indonesia. However, landscape development may destabilize multiple dimension in the current regime that can create a window of opportunity for niche innovation. Hence, this sub-question is formulated to analyze sociotechnical aspects that create barriers and drive small hydropower implementation.

4. How can small hydro power initiatives be stimulated?
   The business models' analysis would also unfold both misalignment and alignment of policies and regulation with the current business models. From identifying barriers, analyzing sociotechnical aspects and business models, in the end, this study aims to provide recommendations to stimulate small hydropower transition.

3.4. Data collection and analysis

3.4.1. Desk research

Two data collection methods are used in answering the research questions: literature study and interview. The literature study is conducted using journal papers, government reports, publicly available laws and regulations, online webinar, online newspaper and company websites. Academic search engines such as Google Scholar, Scopus, ScienceDirect and TU Delft repository are used. Publications from the government such as MEMR, Ministry of Finance, Ministry of Public Works and National Energy Council provided essential data and information on the Indonesia energy sector. Furthermore, secondary data is collected from the company websites (PLN, PT Bumiyasa Indonesia Energi), development agencies (GIZ and IBEKA) and global organizations (World Bank, IRENA, IEA), consulting services (PwC, McKinsey, Deloitte), newspapers (Jakarta Post, CNBC Indonesia, Kompas) and online webinar conducted by renewable energy communities and think-tank organizations (IESR, SRE, Energy Academy Indonesia).

In the present study the literature study is used from the first stage to formulate the problem, identify the knowledge gap and develop conceptual frameworks. In the later stages, the literature study is used to develop the analytical framework for this study and guide interview questions development. Subsequently,

3.4.2. Semi-structured interview

A semi-structured interview is one of the interview methods in exploratory research that allowed the interviewer to include additional questions beyond the list of interview question that has been structured (Edwards & Holland, 2013). Semi-structured interviews are conducted to gather information in the case study and collect insights on the niche level that cannot be gathered using the literature study.

The interview is designed to represent the stakeholders in small hydropower, including the central government, provincial government, incumbent electricity company, private firms, provincial-owned enterprise, cooperatives, development agency, the NGO, research organization, turbine manufacturer and think tank/consultancies. As listed in Table 3.1, potential respondents are selected to encompass actors involved in Indonesia small hydropower so that diverse perspectives and insights are provided. However, during the preliminary interview with experts and online search, the potential respondents might be changed based on the accessibility and other interviewees' references. Potential respondents are contacted through Linkedin, Email and WhatsApp.

Ideally, interviews are conducted using a face-to-face method. Sekaran and Bougie (2016) argue that the face-to-face interview has some advantages. During face-to-face interviews, the principal investigator can seize non-verbal cues from the interviewees, clarify doubt and ensure understanding by rephrasing the questions. However, due to the COVID-19 pandemic, it is not possible to conduct face-to-face interviews. Therefore, the interviews are conducted through an online Zoom meeting, WhatsApp call and phone call. In addition, an interviewee responded the questions through email.

Interview questions are developed from the conceptual frameworks (SNM, MLP and business models). In general, questions related to niche shielding, nurturing (expectation, learning and networking), niche empowerment, and dynamic interaction between multi-level (regime, niche and landscape) are drafted for all respondents. Additional questions about the business model elements are given to actors from business entities (companies and cooperatives).

3.4.3. Data collection steps

Primary data collection will be conducted as the following steps:

1. Literature study and secondary data collection from governments, firms, development agencies and actors involved in small hydropower development
2. Preparing formal letter for request an interview that is likely requested by particular organizations and preparing document related to human subject research ethic and informed consent.
3. Developing interview questions in English, then translated into Bahasa Indonesia. This approach is taken to avoid misunderstanding and ensure the clarity of questions.
4. Initial contact with the potential respondents
5. Schedule the interview based on the availability of the respondents
6. Semi-structured interview with respondents as listed in Table 3.1.
7. Structure insights gathered from interviews
8. Interview coding and analysis

Table 3. 1. List of respondents

No	Actors Type	Organization	Position	Method	Date	Duration
1	Central government	Ministry of Energy and Mineral Resources	Government official	Written interview	19-May-21	
2	Provincial government	Energy and Mineral Resources West Java	Government official	Online zoom interview	8-May-21	60 minutes
3	State-owned company	PT PLN	Manager	Online zoom interview	7-May-21	45 minutes
4	Private company	PT Petro Hidro Optima	Division Head	Online zoom interview	9-May-21	90 minutes
5	Private company	PT Energi Andalas Group	CEO	Online zoom interview	31-May-21	60 minutes
6	Private company	PT Kerinci Merangin Hidro	Staff	Online zoom interview	10-May-21	60 minutes
7	Private company	PT Bumiyasa Indonesia Energi	Technical Manager	WA call interview	7-Jun-21	60 minutes
8	Cooperative	PLTMH Rimba Lestari	Manager	Phone call interview	6-Jun-21	60 minutes
9	Community based	PLTMH Cihikeu Gede	Manager	Phone call interview	28-May-21	60 minutes
10	Global turbine producer	Andritz Hydro	Project Manager	Online zoom interview	7-May-21	60 minutes
11	Local turbine producer / Professional Association	PT Heksa Prakarsa Teknik / Hydro Bandung Association	Owner / R&D Division	Online zoom interview	6-May-21	120 minutes
12	Research organization	Andalas University	Researcher	Online zoom interview	29-May-21	40 minutes

3.4.4. Interview protocol

The principal investigator develops an interview protocol to guide the interview process and ensure ethical aspects are fulfilled during the interview. The full interview protocol and interview questions can be found in Appendix A. In general, the interview procedure is described as follows:

1. Before the interview, the principal investigator explains the informed consent forms and asks permission **to record** the conversation and approval to quote their statements in this thesis anonymously.
2. The principal investigator explains the background and objectives of this study.

3. The principal investigator provided a list of questions in advance for respondents to guide the conversation.
4. The interview is divided into two parts. The first part focuses on the questions related to niche development. In the second part, the business entities' respondents are expected to answer questions related to business model components.
5. On average, the interviews last for 45-60 minutes based on the respondent's availability.
6. After the interview, the recording is **transcribed** within two days to avoid loss of information or miss out on interpretation.

3.4.5. Data analysis

The case study offers the principal investigator to use multiple data sources. Since this study uses two data sources (i.e. interview and secondary data), data triangulation is needed to converge the data and increase the validity (Sekaran & Bougie, 2016). The primary data collected are coded and analyzed using a qualitative data analysis software, ATLAS.ti Scientific Software Development GmbH, version 9.0.24.

3.5. Analytical framework

This section describes how theoretical frameworks will be used and integrated to form an analytical framework for this thesis. SNM will take a central role as the main conceptual framework to analyze small hydropower niche activities. In addition, the MLP concept is added as a complementary insight to assess the selection pressures from the sociotechnical regime and landscape level. Furthermore, the analytical framework that will be developed in this study, as shown in Figure 3.2., will bring together the MLP analysis, niche process analysis through the SNM framework and Osterwalder and Pigneur's business model components. This integration is expected to understand the interconnection between niche development and the role of business models.

Small hydropower development in Indonesia is analyzed using the SNM concept, which includes shielding, nurturing, and empowerment (Smith & Raven, 2012). Since the MLP conceptualizes sociotechnical transitions as the result of dynamic interaction between three levels: regime, landscape and niche (Geels, 2004), the SNM framework is then integrated into the MLP framework and positioned at the bottom part of the MLP framework to add in-depth analysis in niche level. Simultaneously, the role of business models in small hydropower in Indonesia is investigated by using the concept from Bidmon and Knab (2018) that elaborate three roles of business models in sociotechnical transition. In the following section, the framework integration and how it is used for the analysis will be elaborated in more detail.

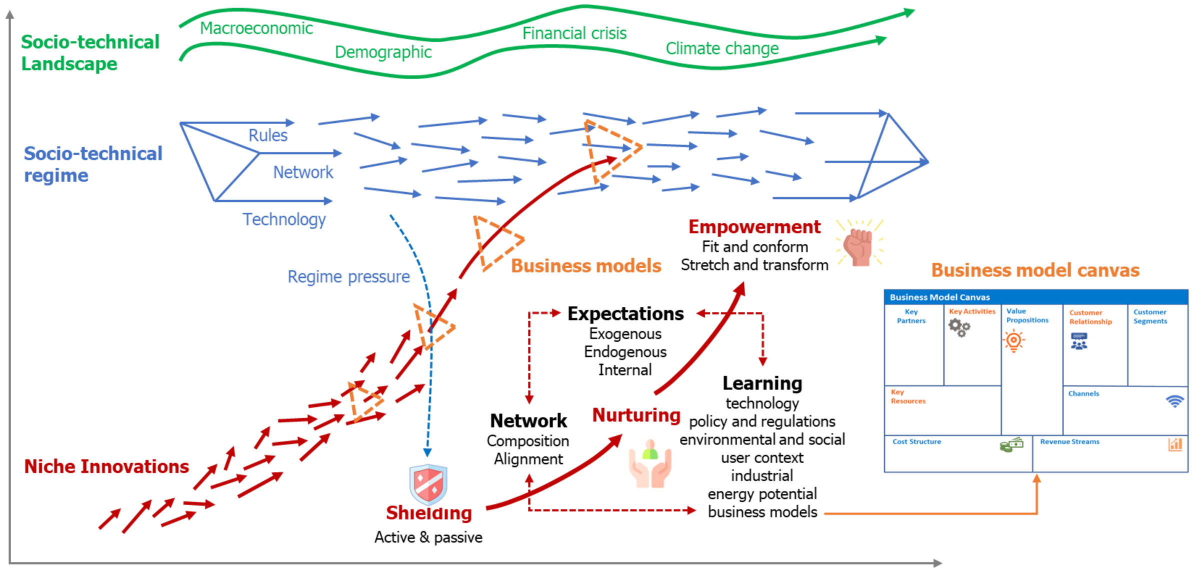

Figure 3. 2. Integrated analytical framework of the MLP, SNM and business model (Adapted from Geels, 2002; Osterwalder & Pigneur, 2010; Smith & Raven, 2012; Bidmon & Knab, 2018)

3.5.1. Niche analysis

Small hydropower in Indonesia is perceived as a niche with protection characteristics identified as niche nurturing, shielding, and empowerment. Therefore, the concepts of the three niche processes will be used to analyze small hydropower development. Table 3.2. shows the analytical framework's overview for analyzing niche processes as elaborated in the following section.

1. **Niche Nurturing**

Niche nurturing consists of three internal niche processes, including network formation, shaping expectation and learning process.

Network formation

Two aspects of network formation that will be analyzed in this thesis include the composition of actors involved in niche development and actor alignment that explain to what extent actors interact in the niche. Stakeholders involved and their interrelation will be mapped to guide the analysis of network formation. Additionally, for small hydropower in Indonesia, the alignment between actors will be evaluated by investigating the cooperation and interaction between various actors in the development process.

Voicing and shaping expectation

This thesis will analyze expectations of niche actors (internal expectations) and other two expectations (i.e. exogenous and endogenous expectations) as introduced by Kamp and Vanheulle (2015) to gain insights on the source of expectations. Exogenous expectations are influenced by landscape development, regime factors and the development of other niches. On the other hand, endogenous expectations emerge as the result of experiments at the niche level. Internal expectations will be evaluated by presenting insights from interviews with niche actors.

Learning process

Seven aspects of learning will be analyzed in small hydropower development. Five aspects of learning mentioned by Hoogma et al. (2002) is investigated in this thesis. The five aspects concern learning of technical development and infrastructure, environmental and societal impact, user context development, government policy and regulations, and industrial development. Kamp and Vanheule (2015) added two more aspects of learning: analyzing the energy potential and learning about the appropriate business model to gain mass-market adoption.

1. Technical development and infrastructure

   It includes technical aspects that have been improved during small hydro power implementation and the surrounding infrastructure might influence the small hydropower development.
2. Policies and regulations

   This aspect is related to learning about regulation, policy and law that influence small hydropower diffusion to the larger market. Furthermore, how incentives, tariff and subsidies could facilitate implementation will be analyzed.
3. User context development

   This learning aspect involves learning how about user requirement, user characteristics, and how users use small hydropower.
4. Industrial development

   The learning process conducted by the global and local turbine manufacturers will be analyzed. Besides, the development of technical standard for manufacturer will be investigated.
5. Environmental and social impact

   This learning aspect is related to niche actors' awareness regarding the social and the environmental aspect of small hydropower implementation in rural areas.
6. Energy potential

   The study about energy potential is a crucial aspect of learning before the implementation of small hydropower.
7. Business model

This learning related to the business model innovation to enter the market, maintain business sustainability and facilitate the transition. This learning aspect will also be covered in detail in the business models analysis part.

2. **Niche shielding**

Two types of niche shielding (i.e. passive and active) can be identified in small hydropower development. Passive shielding is relevant to analyze the development of small hydropower in rural areas that previously have no access to the grid infrastructure owned by the incumbent electricity company. On the other hand, this thesis will evaluate active shielding that has been implemented, such as regulations that protect small hydro power niche, including incentives and subsidies that can encourage business and facilitate small hydropower implementation.

3. **Niche empowerment**

Niche empowerment can be distinguished into (1) fit and conform empowerment and (2) stretch and transform empowerment (Smith & Raven, 2012). The breakthrough process of small hydropower into the Indonesia electricity regime level can be identified using two empowerment concepts. It will be done through analysis of the regulations, policies and business models. In fit and conform empowerment, small hydropower relatively becomes competitive in the electricity sector without changing the regime's selection pressures such as industrial structure, formal institutions, and norms. This study will investigate whether changes in regulations, laws, and incentives are occurred as indicated by stretch and transform empowerment.

Table 3. 2. The analytical framework of the niche level

Niche process	Aspect	Analysis
Nurturing	**Network formation**	Actors composition
		Actors alignment
	Shaping expectation	Exogenous factors
		Endogenous factors
		Internal expectations
	Learning process	Learning about technical development and infrastructure
		Learning about policies and regulations
		Learning about user context development
		Learning about industrial development
		Learning about environmental and social aspect
		Learning about small hydro energy potential
		Learning about business models
Shielding	**Passive shielding**	To what extent niche developed through passive shielding
	Active shielding	To what extent niche developed through active shielding
Empowering	**Fit and conform**	Analysis of the competitiveness of small hydropower in the current electricity regi
	Stretch and conform	Analysis of changes in regulations, laws, and incentives that influenced by niche

3.5.2. Regime analysis

The sociotechnical regime of electricity in Indonesia will be analyzed using three interlinked dimensions of the regime according to Verbong and Geels (2007) that include actors' network, rules and technology. First, this thesis will investigate the dynamic of the actors' network and social groups. Second, the analysis of changes in formal rules such as regulations and laws. Finally, this study will look at the technical development in the electricity sector, including energy resources, grid infrastructure, and power plants.

3.5.3. Landscape analysis

Landscape developments such as macroeconomic conditions, the global issue on climate change and demographic trends, and how these factors influence small hydropower niche development will be discussed using secondary data sources and insights from interviews.

3.5.4. Business model analysis

Small hydropower development in Indonesia is investigated using the SNM and the MLP framework to understand the sociotechnical aspects. However, the organization of the small hydropower sector can also be analyzed using business models. In this thesis, small hydropower barriers and opportunities are investigated together with their relationship to business models' roles. It is essential because the current business models can either reinforce the regime's dynamic stability or new business models create a new industrial recipe, as argued by Bidmon and Knab (2018). The analysis will be conducted to examine whether the regime actors utilize the existing business model to exert pressure on niche innovation to grow and create barriers to sociotechnical transition or new business models being developed to break through into the regime level.

This thesis will analyse business models in the small hydropower sector using the business model canvas from Osterwalder and Pigneur (2010). It is selected as an appropriate tool because it offers a complete element (i.e. nine building blocks) to understand how actors organize this sector and identify the diversity of small hydropower business models currently being implemented in Indonesia.

4. Small hydropower development in Indonesia

This section aims to answer the first sub-research question, "How have small hydropower actors in Indonesia been involved in niche processes?". This question will be answered by explaining several topics. First, the technology description of small hydropower will be explained in brief to guide the reader to comprehend the development of small hydropower in Indonesia. Second, the historical development of small hydropower in Indonesia is depicted. Third, a stakeholder map is elaborated to inform the Indonesian electricity sector structure, renewable energy policymaking, and stakeholders' roles and responsibilities. Finally, the essential formal institutions as guidance for the electricity sector and renewable energy development is explained.

4.1. Technology description of small hydropower

The basic knowledge of small hydropower may be helpful for readers who are not familiar with this technology to follow the discussion on technical aspects in this thesis. Therefore, this section will first describe the fundamental concept of how the potential energy of the water can be converted into kinetic energy to produce electricity. Various engineering disciplines such as civil engineering, mechanical and electrical engineering comprise a small hydropower system. Components from each engineering disciplines will be described briefly. From the brief explanation of small hydropower technology, it is expected that niche activity related to learning about the technology can be comprehended.

4.1.1. How a hydropower plant works

Hydropower technology is a robust and mature technology developed 2000 years ago through a technological evolution from wooden waterwheels for milling grain to large scale hydropower plant for generating electricity (Paish, 2002).

A hydropower plant harnesses the energy potential of the water to turn turbines, which is then transferred by mechanical shaft power to rotate the generator and produce electricity. The produced power, in general, can be calculated by multiplying the flow rate pass through the turbine and the net pressure head of water. Net pressure head is calculated by incorporating energy loss of water in civil components. Additionally, the efficiency of the turbine, mechanical transmission, and generator must be taken into account. Hence, the general formula to calculate power output is (Paish, 2002):

$$P = \rho g Q H \eta$$

Where P is the power output (Watts), ρ is the water density (kg/m^3), g is the acceleration due to gravity (m/s^2), Q is the water flow rate (m^3/s), H is the net pressure head (m), and η is the efficiency of the turbine, mechanical transmission and generator.

4.1.2. Hydropower classification

The hydropower plant can be classified into large and small-scale hydropower. According to Paish (2002), small hydropower has a maximum capacity of 10 MW. It consists of smaller size, including mini-hydro with a range capacity from 500 kW to 2 MW, micro-hydro from 10 kW to 500 kW, and pico-hydro refers to capacity below 10 kW. However, the extant literature shows different classifications and definitions of small-scale hydropower. Kaunda et al. (2012) review the literature on hydropower and summarize the different classification set by various countries and organization based on the installed capacity, as shown in Table 4.1.

Table 4. 1. Small hydropower classification based on installed capacity (Kaunda et al., 2012)

Country/Organization	Installed Capacity (MW)
China, Canada	≤50
USA, Brazil	≤50
India	≤25
United Kingdom	≤20
France, Norway, Portugal, Spain, Ireland, Greece, Belgium, South Africa, ESHA, International Energy Agency, World Commission on Dams	≤10

Table 4.1. shows that several European countries and organizations define small hydropower as a power plant with installed capacity below 10 MW. The maximum 10 MW classification has been most widely adopted by many countries (Erinofiardi, 2017), including Indonesia (ESDM, 2017). The Ministry of Energy and Mineral Resources of Indonesia categorizes mini-hydro power as a subset of small-hydro power with an installed capacity between 100 kW and 5 MW and micro-hydro power below 100 kW (EBTKE, 2020). Above the maximum limit of 10 MW, hydropower is considered a large-scale project.

4.1.3. Technology map

Several technological components comprise a small hydropower system. In this section, essential technological elements are investigated, divided into four main components: civil work components, electromechanical, transmission and distribution, and the surrounding system. These components are interrelated and interdependent on each other, determine technical design and also influence niche development. The technology map will show the technical components that comprise the power plant system and value chain in the small hydropower sector.

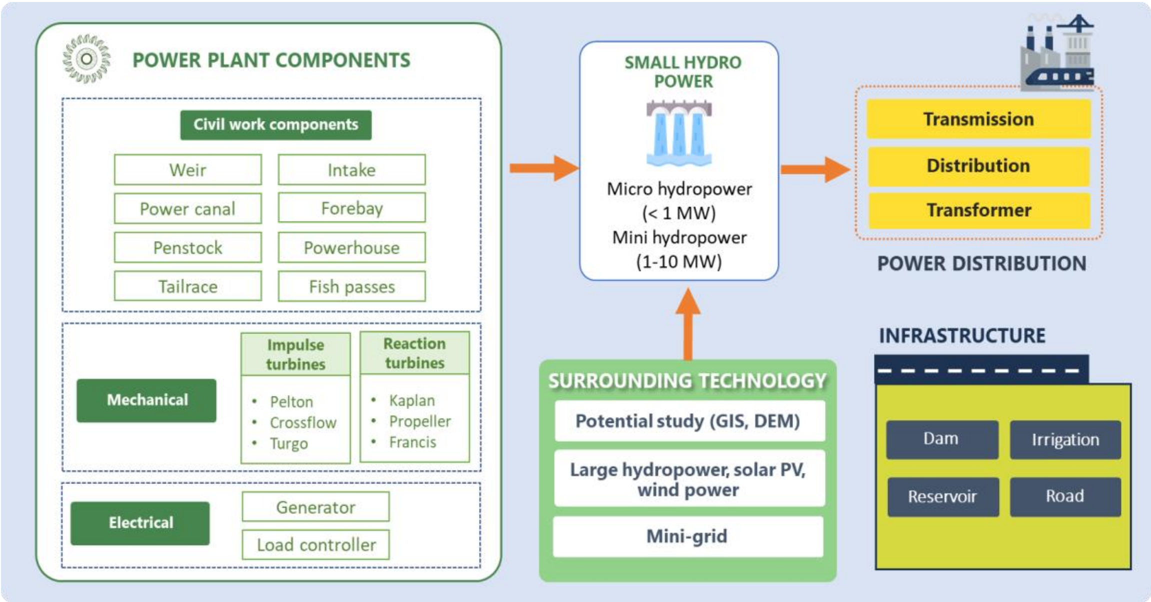

Figure 4. 1. Small hydro power technology map

1. Civil work components

The civil work components pipe the water from the main river stream to the powerhouse with lower elevation to get optimal potential energy to turn the turbine blades. From the upstream to the downstream, the civil work components consist of the weir/low dam, intake, power canal, forebay, penstock, powerhouse and tailrace. The description of the civil engineering component will be helpful as the technical learning process in the niche influence the various design combinations in different locations.

Weir

In the run-off river scheme, water is diverted to the intake and the power canal by using a weir. A weir is a permanent embankment with sufficient height to raise the river's water level so that a required flow rate design can be maintained for turning the turbine blades. Since small hydropower does not require a huge dam for the water reservoir and only utilizes a relatively small weir, it has a lower environmental impact than large scale hydropower (IRENA, 2015)

Intake

The intake is used to divert the water from the main river flow and flow it to the turbine. It is equipped with a trash rack (filter) to prevent unintended objects such as trashes and twigs that can damage the turbine.

Power canal

The power canal is built to pipe the water from intake to the forebay. There are various kinds of power canal, including open channel, tunnel and closed channel. It is necessary to complement the power canal with spillways within a certain distance to overflow the water if there is a flood.

Forebay

The power channel will end in the forebay. The water flow through the power channel may include sand and mud. Therefore, the forebay is used to settle sand or mud so that the water is relatively clean when entering the turbine. The forebay is usually built by widening and deepening the end section of the power channel. The forebay is equipped with a spillway to maintain the water level and a drain to clean the sediment.

Penstock

From the forebay, water is conveyed through the penstock to the powerhouse. It can be installed above ground or under the ground, depending on the environmental condition and penstock material. Penstock is usually installed in a straight line with several bends in the upstream, middle part, and end section before entering the powerhouse. Anchor blocks support the penstock on each bend to resist thrust and frictional forces due to expansion and contraction. The support block serves to hold the penstock between the anchor blocks so that the load carried by the anchor block is not too heavy. The penstock design should consider several aspects: ground condition, acceptable frictional losses, internal hydraulic pressure, site accessibility, and cost. This aspect determines penstock diameter, wall thickness and material.

Powerhouse

Powerhouse plays a vital role because the main mechanical-electrical components such as turbine, generator and electrical panel are installed inside this building. The heavy mechanical and electrical equipment need a stable foundation of the powerhouse since the performance of the turbine and generator can be influenced by settlement. Therefore, the study about the ground geological condition must be conducted to ensure the foundation stability before the powerhouse construction (Penche, 1998).

In general, small hydropower strives to achieve maximum head. Consequently, the powerhouse must be located at the lowest possible elevation. On the other hand, placing the powerhouse at the elevation close to the river's water level is at risk of being exposed to river floods. Therefore, for safety reasons, the powerhouse must be built higher than the river water level considering the historical data of river water levels.

Tailrace

The water discharged from the turbine is conveyed back to the river through the tailrace. Tailrace should be designed to protect the powerhouse from the impact of the high velocity of water discharged out of the turbine. The canal with a concrete apron or rock riprap is often used to protect the powerhouse from the wild discharged stream.

Fish passes

Small hydropower should not have negative impacts on biodiversity, such as fish and interference fisheries. Although small hydropower uses a relatively small weir, it potentially damages fish. Fish passageway should complement weir to allow fish to move from upstream to downstream or vice versa. Fish ladders can be designed to accommodate fish movement. However, to achieve the best design, the engineer should consult with biologists, so the passageway can facilitate the type of fish in a particular river as they can be surface swimmers, bottom swimmers or orifice swimmers (Penche, 1998).

2. Electromechanical components

Turbine

Indonesia has a diverse topographic variation. Rivers may flow through mountainous areas that have large differences in elevation, and they may also pass through relatively flat areas. This condition influences the turbine type because the selection of the turbine is based on the combination of the head and flow range that is available at the site.

Turbine designs are grouped into two main categories: impulse and reaction turbines (Okot, 2013). The impulse turbine utilizes kinetic energy from the jets of water to move turbine buckets or vanes. The high pressure from jets of water is typically achieved in sites with a high head and low flow. Some turbine types are categorized into impulse turbine, including Pelton turbine, Cross-flow turbine and Turgo turbine. The criteria have been set to guide the selection of turbine based on the variation of head and flow available at the site; see Figure 4.2.

The low head turbine is often installed in micro hydropower that harnesses irrigation channel with a little topographic variation. Reaction turbines such as Kaplan, Propeller, and Francis turbines are suitable for sites with low head. Moreover, an improvement on the open flume propeller turbine makes it possible to operate at the lower head less than 4 meters.

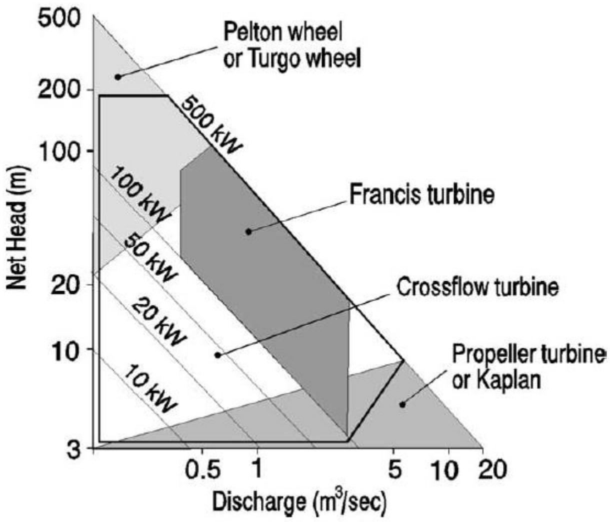

Figure 4. 2. Turbines selection guide for given net head and flow (Reprinted from Paish, 2002: 543)

Generator

A generator converts mechanical energy (i.e. turbine rotation) into electrical energy. The generator has a fixed part, namely the stator and a rotating part called the rotor. The stator is formed from coil wire, whereas the rotor is a mechanical component that is connected to the turbine. The rotor rotation driven by the turbine will cause a change in magnetic flux in the coil that generates electrical energy.

A generator shall be equipped with a control system to regulate the speed and voltage on the generator. Ensuring the constant voltage and frequency can be done through two methods. First, using a governor regulates the valve to adjust the water flow into the turbine to balance the power demand variation. Second, installing an electronic load controller (ELC) balances the power load with the generator output power to protect the turbine from runaway speed that potentially undermines the turbine when a significant load change occurs. The ELC will transfer the excess power to the ballast load so that the generator output will be stable even though there is a change in the main load (Paish, 2002).

3. Transmission and distribution

The power transmission line is explicitly determined by the distance from the power plant to the demand location or the nearest existing electricity grid. Furthermore, the transmission line can potentially impact the environment, such as intrusion on the visual landscape and endanger birds due to the collision with the transmission line (Penche, 1998). These factors must be considered for choosing the alternative design of the transmission line, whether it is built overhead or using the underground cable. Hence, the construction cost of the transmission line can be a considerable proportion of the overall investment cost of small hydropower (Okot, 2013).

In Indonesia, small hydropower potential is located mostly in remote and hilly areas, making it difficult to access through the national electricity grid. A long-distance transmission line to remote areas is inhospitable for the national grid. It means that the cost will be high for state-owned electricity companies and would not be feasible. Therefore, off-grid power plant from locally available renewable resources such as wind, solar and hydro might be the suitable solution.

4. Surrounding system

Hydropower potential assessment

To increase the data accuracy of hydro energy potential where historical hydrological data is not fully available, recently researchers utilizing Geographical Information Systems (GIS) and Digital Elevation Model (DEM) (Tamm & Tamm, 2020; Tian et al., 2020). These methods are helpful for mapping the appropriate location for developing small hydropower

According to Hoes et al. (2017), hydropower energy potential can be categorized into three:

- The gross theoretical potential calculates all the hydropower potential available, assuming that all the potential would be used to generate electricity.
- The technical potential includes all attractive and available potential location that the existing technology can exploit.
- The economically feasible potential presents the potential electricity generating capacity after considering the economic aspect in the feasibility study that could generate a positive outcome.

In mapping the potential, some factors such as environmental and regulatory can be considered using GIS. For example, when dealing with natural protected areas, GIS can extract this location straightforwardly. However, GIS has a limitation when dealing with social and operational aspects (Tamm & Tamm, 2020).

Irrigation system

Compared with large scale hydropower plants that require a big reservoir and large dam construction that potentially negatively impacts the downstream of the rivers. Small hydropower relatively has minimum effect since it is designed as a run-off river system. In this installation method, the power plant is built close to the river and harness small flow diversion from the river's main body. A small weir's construction is sufficient to divert the small part of the river flow with minimum disturbance to the main river flow. The potential conflict with other water use such as irrigation system and other water users located downstream should be reduced, and this design can improve environmental sustainability.

Indonesia, as an agricultural country, has many rice fields supported by an extensive irrigation network. Alongside the rivers' potential, an extended length of irrigation network adds a considerable amount of energy potential that can be harnessed. According to Pranoto et al. (2018), Indonesia has more than 48 thousand irrigation area that may appropriate for small hydropower development. Nevertheless, the study on the potential of irrigation channels for small hydropower is still lacking. In their paper, Pranoto et al. (2018) contribute to mapping micro-hydro potential at an irrigation network in Serayu Opak River Basin that indicate around 26 MW in total, in which 19 irrigation channels has a capacity of more than 50 kW. This study showed that a single river basin connected to an irrigation network with many potential locations along its channels could be developed as small-hydro power plants.

Road access

The road is a vital infrastructure to support the power plant's construction process since equipment and materials need to be mobilized to the site. However, in most cases, road access is not sufficiently available to reach remote areas in Indonesia. Independent Power Producer needs to pay attention to the road and bridge access to the potential location of small hydropower. Additional cost to construct appropriate road access and bridge as supporting infrastructure for transporting heavy civil and electromechanical equipment to the site must be considered in advance (Suryanto, 2021).

Mini-grid technology

Power generation from renewable energy sources often faces the intermittency challenge. However, small hydropower relatively has constant energy production compare with solar PV and wind power. Consequently, renewable energy developers improve the system and use a mini-grid system that incorporates two or more renewable energy systems. In Indonesia's rural area, the most mini-grid system combines micro-hydropower with solar PV. Some of the mini-grid projects also install wind power to increase the reliability of the system. Battery storage technology also becomes an essential component in the mini-grid system as a complementary technology to store the excess power and solve supply intermittency problem.

4.2. Small hydropower Potential

According to Erinofiardi et al. (2017), micro-hydropower in Indonesia is slowly developed. ESDM (2017) reported that Indonesia has around 19 GW of micro and mini-hydro power's total potential capacity. As shown in Table 4.2. Kalimantan Island has the most considerable potential with 8,1 GW. Sumatera island in the second position with approximately 5,7 GW potential capacity, followed by Java (2,9 GW), Sulawesi (1,6 GW). The big islands in the eastern part of the country have relatively smaller SHP energy potential, in which Papua and Maluku have 618 MW and 214 MW, respectively. With only 141 MW, Bali and Nusa Tenggara is the island that has the smallest potential capacity.

Table 4. 2. Micro and mini-hydropower potential (in MW) in Indonesia (ESDM, 2017)

No	Province	Potential
1	Kalimantan Timur	3562
2	Kalimantan Tengah	3313
3	Kalimantan Utara	943
4	Kalimantan Barat	124
5	Kalimantan Selatan	158
Kalimantan Island		**8100**
6	Aceh	1538
7	Sumatera Barat	1353
8	Sumatera Utara	1204
9	Sumatera Selatan	448
10	Jambi	447
11	Lampung	352
12	Riau	284
13	Bengkulu	108
Sumatera Island		**5734**

No	Province	Potential
14	Jawa Timur	1142
15	Jawa Tengah	1044
16	Jawa Barat	647
17	Banten	72
18	Yogyakarta	5
Java Island		**2910**
19	Sulawesi Selatan	762
20	Sulawesi Tengah	370
21	Sulawesi Tenggara	301
22	Gorontalo	117
23	Sulawesi Utara	111
24	Sulawesi Barat	7
Sulawesi Island		**1668**

No	Province	Potential
25	Papua	615
26	Papua Barat	3
Papua Island		**618**
27	Maluku	190
28	Maluku Utara	24
Maluku Island		**214**
29	Bali	15
30	Nusa Tenggara Timur	95
31	Nusa Tenggara Barat	31
Bali-Nusa Tenggara		**141**
Total Potential		**19385**

Currently, no updated information is available from the government on the number of SHP plants installed. However, a web-based interactive map of renewable energy installations created by GIZ shows that Indonesia has 357 micro-hydro power plants spread throughout rural areas in the archipelago (Energizing Development of Indonesia, 2020). In terms of the installed capacity, according to the Ministry of Energy and Mineral Resources (2020), micro and mini-hydro power plants have been installed around 106 MW and 311 MW, respectively. This number needs to be increased quickly in the upcoming years as the target set in Presidential Regulation No. 22 of 2017 aims for reaching 3.000 MW by 2025.

4.3. Historical development of small hydropower in Indonesia

The historical development of small hydropower describes how the technology has been introduced, used and developed. It will cover technical and institutional aspects such as changes in the government and policies that influence technological development.

4.3.1. The primary energy source in the past

Small hydropower has been an essential part of the power generation in the history of Indonesia's electricity. According to Widmer et al. (2001), small hydropower was first introduced at the end of the 19th century for powering tea factory during the Dutch East Indies colonial era. Many tea plantations were opened in the mountainous rainforest of West Java as it offers fertile volcanic soil with high rainfall and suitable temperature. Since rivers with elevation difference typically can be found in the mountainous area that provide the potential of hydraulic resources, this condition creates a perfect match between tea factories and small hydropower technology.

According to Harijono et al. (2021), The Dutch East Indies government, on 13 September 1890, allowed private firms to participate in the electricity sector. Among nineteen private firms involved in the electricity business, twelve firms operated in Java, whereas the others were located in Sumatra, Kalimantan, Nusa Tenggara Barat, Sulawesi Selatan, and Ambon. One of the companies, namely Nederlandsch Indische Waterkracht Exploitatie Maatschappij (NV. NIWEM), focused on hydro power plant development. It operated three small hydropower plants in Malang East Java (i.e., PLTA Mendalan, PLTA Sengguruh and PLTA Siman).

Hydro power plants and coal-fired power plants played a vital role in providing electricity for industries and public services. However, the Dutch Government prioritized hydro power as indicated by establishing a dedicated subdivision under the Department of Government Enterprises, namely the Service for Water, Power and Electricity, in 1917 (Sambodo, 2017). The involvement of the private sector in small hydropower development received special attention from the Dutch Government. This independent subdivision regulated a water concession permit for small hydropower (under 75 kW) and large hydropower plants (more than 75 kW). For small hydro power plants, the concession period is unlimited, whilst large hydropower limited to forty years (Sambodo, 2017).

Besides supplying power to tea factories, hydro power was also integrated into the grid and used to supply households, railways, radio stations, and other industries such as sugar factories and rubber plantations (Nurdianto, 2017). At that time, the electricity system was developed and operated by the government and private sectors. As the demand grew and private firms became actively involved, at the end of 1942, the Dutch East Indies government issued 120 permits for electricity concession for 300 locationS in the Indonesia archipelago (Harijono et al., 2021). Particularly for small hydro power plants, around 400 units were installed throughout Java until 1925 (Widmer et al., 2001).

In the Japanese era, all Dutch electricity companies were deprived by the Japanese and put together in a single entity, namely Djawa Denki Djigyo Kosha. Unlike the Dutch East Indies that used electricity primarily for business purposes and public services, during World War II, under Japanese occupation, power plants and transmission grids were perceived as vital objects in war and used as defence tools (Harijono et al., 2021). The shift in the purpose of electricity caused many small hydro power plants that served business activities to be dismantled along with the abandoned tea industries during World War II (Widmer et al., 2001). Up till now, only a few of the remaining small hydro power plants remain in operation (Hardjomuljadi & Siswoyo, 2012). Among those power plants, seven small hydro power plants in West Java are still operated by PT Indonesia Power (a subsidiary of PT PLN), including PLTA Bengkok Dago (3,85 MW), PLTA Plengan (6,87 MW), PLTA Parakan Kondang (9,90 MW), PLTA Ubrug (18,36 MW), PLTA Kracak (18,90 MW), PLTA Cikalong (19,20 MW) and PLTA Lamajan (19,56 MW) (Astutik, 2019).

During the Japanese era, the main focus was reinforcing the defence during the war. However, the Japanese also developed electricity systems such as the construction of 30 kV transmission in Central Java (Ketengger-Purwokerto and Ketengger Tegal) and projects related to the improvement of hydro power plants such as the construction of water channels to increase water debit for PLTA Lamajan, PLTA Plengan and PLTA Ketengger (Harijono et al., 2021). Other projects were carried out to repair hydro power plants (PLTA Siman and PLTA Mendalan) after being attacked by the Japanese during World War II. Unfortunately, these projects were implemented using forced labour (Harijono et al., 2021).

After its independence, Indonesia's electricity sector management transformed from the government and private firms' participation to complete government control. In this phase, the government perceived the electricity sector as a national sovereignty symbol. Indonesia's newly established government carried out a nationalization program of formerly Dutch-owned electricity companies. This program was accomplished in 1957 when all the remaining Dutch-owned companies had been expropriated using a three hundred million rupiahs additional budget (Nurdianto, 2017).

Two months after the declaration of independence, on 27 October 1945, the President of Indonesia, Soekarno, established the first national electricity and gas company, namely Djawatan Listrik dan Gas (Harijono et al., 2021). It became an important milestone for Indonesia, so Soekarno declared the day in 1960 as "the National Electricity and Gas Day" which was formalized in a Ministerial Decree (Anto, 2017). In his speech on the fifteenth anniversary of the National Electricity and Gas Day, Soekarno envisaged that Indonesia would transform not only into an agricultural country but also into an industrial country that would entirely rely on electricity.

In sum, small hydro power has played different roles in different eras. During the introduction phase, it was used to power up tea industry, and public services. Later on, it transformed into war infrastructure supporting the country defence line in the Japanese occupation period. Afterwards, it became a national sovereignty symbol as Indonesia gained independence. The newly born Indonesia focused on rehabilitating power plants and transmission that were attacked or lacking maintenance during the war.

4.3.2. Small hydropower for distributed small scale power generation

A challenging geographical condition in Indonesia motivated the Government of Indonesia through PLN to develop distributed small-scale power generation for rural electrification. Rural electrification was one of the development goals in the electricity sector since the Second President of Indonesia, Soeharto, set the first five years of development program plans (REPELITA I) from 1969 to 1974. In 1968, the primary power plants were dominated by large scale hydropower, large scale diesel power plants, coal-fired power plants and gas-fired power plants with a total installed capacity of around 542 MW. At the same time, PLN had also constructed 197 distributed small-scale power plants with a total installed capacity of around 123 MW consisting of small hydropower and diesel power plants. However, small scale diesel power plants were selected as the dominant technology used for distributed small-scale power generation than small hydropower. In Java and Sumatra, 104 diesel power plants were installed, which vastly outnumbered small hydro power plants for which only around 14 units were installed.

Although small hydro power was a dominant technology during the Dutch colonial period, as the government accelerated the electrification program for rural areas, it was not the first option. Despite having a higher cost per kWh, small-scale diesel power plants were favoured for distributed small-scale power generation because they could be mobilized and constructed in a faster way (Wicaksono, 2017). Since the reign of Soeharto , small-scale diesel power plants have been proliferating and installed in many rural areas. Currently, 5,200 units of small-scale diesel power have been installed in 2,130 locations (Tasrif, 2021, 35:10).

Nevertheless, small hydro power was still perceived as a good option for rural area electrification considering the availability of local resources. At the end of 1974, the Government of Indonesia had accomplished 675 KW of micro-hydro power plants in rural areas, among them the PLTMH in Karanganyar Central Java (75 KW) and the PLTMH Karang Asem (12 KW) (Harijono et al., 2021). However, after 1979, small hydro power had not been implemented at a wide scale. From 1979 to 1984, PLN focused on developing decentralized power plants, many of them being coal-fired (e.g. PLTU Suralaya 2x400 MW and PLTU Muara Karang 2x200 MW) or by large hydro power (e.g. PLTA Saguling 4x175 MW and PLTA Cirata 4x125 MW) (Harijono et al., 2021).

Only after 1990, international donors and development agencies reintroduced small hydro power to provide renewable energy for rural electrification. According to AidData (2016), international donors from the UK, Switzerland, Germany, Norway, the Netherlands and South Korea provided funding to small hydro power plant development with a total grant of approximately US$ 21.2 million between 1997 and 2013 (See Table 3). Some of these projects were not dedicated only to small hydro power development but also to encourage other renewable energy technologies like solar, wind power, and biogas. The grants from international donors contributed to the introduction of small hydro power technology for rural electrification. The implementing agencies transferred knowledge regarding the technology, operation and maintenance.

Table 4. 3. International grants for small hydropower development. Data from AidData (2016)

No	Year	Donor country	Implementing agency	Financing agency	Title	Grant (USD)
1	1997	United Kingdom		DFID	Mini Hydro Project Grant	435,807
2	1997	Switzerland	Skat Foundation	FA	Mini-Hydro: Technical Assistance	588,113
3	2000	United Kingdom		DFID	Mini Hydro Project Grant	31,174
4	2001	Germany		GTZ	Small Hydro Power for Sustainable Economic Development	2,350,945
5	2004	Norway		NORAD	Small Hydro Power Plants Feasibility Study	107,557
6	2005	Netherlands	Senternovem	MFA	Improve electricity access for the rural population in Indonesia	11,548,480
7	2006	Global Environment Facility (GEF)	Indonesia (MEMR)	UNDP	Integrated Microhydro Development and Application Program (IMIDAP), Part I	2,520,215
8	2009	Norway	Tinfos AS	NORAD	Small Hydro Plant - Sulawesi - Indonesia	96,804
9	2010	Netherlands	WWF	MFA	PNPM Micro-Hydro programme	1,471,741
10	2012	Korea	Public-Private Partnership (PPP)	KOICA	Indonesia Cipta Gelar Village Micro Hydro Power Project	97,037
11	2012	Netherlands	Yayasan Sepakbolaplus Indonesia	MFA	PNPM Micro-Hydro programme	744,892
12	2012	Korea	Public-Private Partnership (PPP)	KOICA	Indonesia Cipta Gelar Village Micro Hydro Power Project	97,037
13	2013	Norway	ICH - International Centre for Hydropower	MFA	Course in Operation and Maintenance - Hydropower	60,011
14	2013	Norway	ASDB - Asian Development Bank	MFA	Development of clean energy to Sumba Island.	1,028,754
15	2013	Korea	Public-Private Partnership (PPP)	KOICA	Indonesia Cipta Gelar Village Micro Hydro Power Project	68,795
Total						**21,247,362**

4.4. Stakeholder map

Small hydro power is part of the broader electricity system in Indonesia. Indonesia's electricity system is characterized as a complex system that consists of many stakeholders involved in governance, policymaking, and business. Hence, a stakeholders map will be helpful to give an overview and explore in detail the key actors, regulations, policies and informal institutions.

Considering the diversity of actors involved in developing small hydropower, delineation of involved actors is necessary. The Indonesia small hydro power actor map is depicted in Figure 2. The actor map can be seen vertically based on the multi-level relationship between policymaker, the small hydropower industry, international donors and external stakeholders. At the bottom part, the value chain is drawn horizontally.

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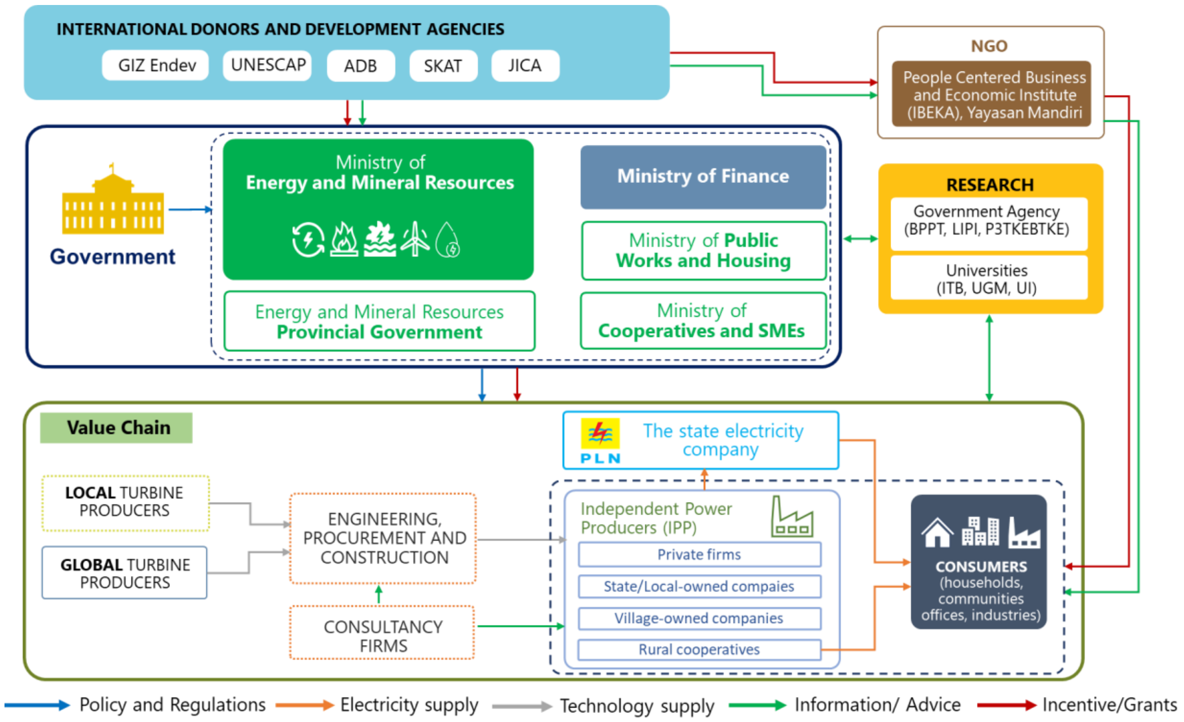

Figure 4. 3. The actor map of small hydropower in Indonesia

The central government established the National Energy Policy (Presidential Regulation No. 79 of 2014) as a long-term energy policy. In this regulation, renewable energy should contribute 23% of the national energy mix in 2023. Based on National Energy Policy's target, the government issued The National Energy General Plan (Presidential Regulation No. 22 of 2017) as elaborated action plans and strategy for the intersectoral implementation of renewable energy.

4.4.1. The ministries

The Ministry of Energy and Mineral Resources is responsible for creating regulations and policies in the energy sector. It has a special agency regulating the electricity sector, namely the Directorate General of Electricity and Energy Utilization (DJLPE). DJLPE plays a role in supervising the state-owned electricity company (PLN) and independent power producers. The Ministry of Energy and Mineral Resources works through the Directorate General of New and Renewable Energy and Energy Conservation to develop new and renewable energy (ESDM, 2021). The Ministry of Finance regulates fiscal incentives for electricity producer and subsidies for the customers to encourage renewable energy implementation (Yudha & Tjahjono, 2019). The Ministry of Public Works and Housing is involved in developing small hydropower through the Directorate General of Water Resources as it is responsible for regulating water management, dam and reservoir (Pusair Irigasi, 2019).

The government consider that small hydropower projects do not only bring benefit to rural communities in terms of electricity but can also drive the economy through empowerment of cooperatives and small-medium enterprises as the small hydropower owner or operator (Munthe, 2014). Therefore, the Ministry of Cooperatives and SMEs is essential for creating policy and regulation that support small hydro power SMEs and rural community development.

4.4.2. The parliament

The parliament plays a role in the approval of laws for the energy and electricity sector, including the National Energy Policy (KEN), the National Energy General Plan (RUEN), and the Electricity General Plan (RUKN) (Maulidia et al., 2019). Furthermore, the Indonesia parliament is facilitating the renewable energy transition to mitigate climate change through deliberating the new and renewable energy bill that is expected to be completed by the end of 2021 (The House of Representatives, 2021).

A parliamentary member of commission VII, Dyah Roro Esti in Society of Renewable Energy Webinar in 2021 argues several reasons why renewable energy regulation is needed (Esti, 2021). First, currently, there are various existing laws and regulations regarding the governance of renewable energy created by different stakeholders that need to be aligned. For example, based on the Minister of Energy and Mineral Decree No. 225.K/30/MEM/2020, the Government set a policy for providing subsidies for coal-based power generation by setting the maximum coal price at US$ 70 per ton in any given global price fluctuations. Therefore, coal-based electricity producer for the public gets a guarantee of low coal prices. However, this policy is contra-productive for renewable energy power plants. Second, the existing regulations are not optimal for encouraging and supporting investors to invest in renewable energy. Third, regulations for renewable energy development issued by relevant ministries are considered inconsistent at the ministerial level. However, Indonesia's Government aims to create a conducive climate for investors, particularly in the renewable energy sector, to make Indonesia more investor-friendly. Finally, renewable energy sources need to be supported in order to become competitive in the energy market. This rationale is in line with the SNM concept that sustainable energy technology as a niche needs to be protected.

4.4.3. International donors and development agencies

International development agencies such as GIZ and SKAT jointly work with international donors such as ADB, UNESCAP and JICA to develop micro-hydropower in Indonesia. GIZ support any public or private initiatives in providing electricity access to rural areas. GIZ does not only have financial resource but also provide experts to supervise the renewable energy projects such as micro hydro power. They also share knowledge with rural communities, cooperatives, and local manufacturers to build the capacity of local people to manage and operate micro-hydropower in their village as a modern energy source for the household. Endev Indonesia also encourages the uses of electricity for productive application to ensure business sustainability and develop the local economy (Humas EBTKE, 2019).

In 2005, GIZ launched a program called Energizing Development (Endev) Indonesia. Endev Indonesia is a collaboration program between GIZ and the Ministry of Energy and Mineral Resources through the Directorate General for New and Renewable Energy and Energy Conservation (EBTKE). Multiple international donors support this program through partnerships between government institutions that involve the German Federal Ministry for Economic Cooperation and Development, the Dutch Ministry of Foreign Affairs, the Swiss Agency for Development and Cooperation, and the Norwegian Agency for Development Cooperation. Endev (2020) reports that 286 SHP plants and mini-grid with a range of capacity from 5 to 400 kW have been installed to provide people in rural areas with access to electricity.

In 2013, the Government of Indonesia established a grant management institution, namely Millennium Challenge Account-Indonesia (MCA-Indonesia), to implement the Green Prosperity (GP) program funded by Millenium Challenge Corporation (MCC). The GP program provided grants for four on-grid renewable energy projects and 24 off-grid projects, including hydro, solar and bioenergy, with a total capacity of 12.73 MW (Millenium Challenge Corporation, 2019). Between 2015 and 2017, MCA Indonesia provided grants for institutions such as IBEKA, WWF Indonesia and Penabulu Foundation to develop 13 micro hydro power plants in Indonesia (Social Impact, 2019).

4.4.4. Local NGOs

The People-Centered Business and Economic Institute (IBEKA), a local NGO chaired by Tri Mumpuni, is a niche actor that actively develops micro-hydropower plants in rural areas throughout Indonesia. IBEKA aims to provide electricity access that is expected to increase economic activities in rural areas through the villagers' active participation in the cooperative business model (IBEKA, 2021). Furthermore, IBEKA empowers people in rural areas involved in managing and operating power plants. The new power plants and electricity generated may lead to new business opportunities, increase employment and eventually alleviate poverty. This cooperative business model has a significant role in the diffusion of SHP technology in rural areas. From 1992 to 2018, IBEKA has constructed 65 SHP plants in Sumatera, Java, Kalimantan, Sulawesi and Nusa Tenggara. These plants range between 0.5 and 170 kW, with a total installed capacity of 2,636 kW (IBEKA, 2021).

In 2010, IBEKA collaborated with Hivos and Winrock International to initiate a renewable energy project called Sumba Iconic Island (SII) to provide electricity access for 750,000 people in Sumba Island. The total grant for this program is 7 million Euros, funded by three international donors, including Millenium Challenge Corporation (46%), the Netherlands Directorate General for International Cooperation (40%) and the Norwegian Embassy (14%). Sumba Iconic Island (SII) developed renewable energy alternatives consisting of 12 micro-hydropower plants, 15,000 solar PV installations, 1,173 biogas plants, and 100 wind turbines. As a result, this program contributed to the increasing electrification ratio in Sumba Island from 24.5% in 2010 to 42.67% in 2015 (Hivos, 2020).

Another local NGO, Yayasan Mandiri, has been involved in building micro hydro power plants since 1986. For the first time, Yayasan Mandiri constructed micro hydro power in 1986 in Subang, West Java, with support from the Government of New Zealand. In the same year, Yayasan Mandiri also received a grant from the German Government. Yayasan Mandiri has actively developed guidelines for the operation, maintenance and preparation of micro hydro power plants. It also conducts training for micro hydro power plants operators and developers (Hindrakusuma, 2007).

4.4.5. Electricity producers

The incumbent electricity producer in Indonesia is a state-owned electricity company (PLN). The role of PLN in Indonesia's electricity sector is dominant under monopoly regulation. PLN involves in the whole supply chain of electricity, including power generation, transmission and distribution. In addition, as mandated by the government, PLN is responsible for developing electricity infrastructure to supply the whole population. Besides PLN, the government also open opportunities for Independent Power Producers (IPPs) to participate in the power generation sector. The incumbent electricity producer in Indonesia is a state-owned electricity company (PLN). Besides PLN, the government also open opportunities for Independent Power Producers (IPPs). IPP is defined as a special purpose company to build, operate and own a power plant under a power purchase agreement (PPA) with PLN (PLN, 2021). IPPs in Indonesia consists of private firms, state-owned company (BUMN), local-owned company (BUMD), village-owned company (BUMDes) and cooperatives. A local-owned company in West Java, PT Tirta Gemah Ripah, with a core business in drinking water supply, also participates in the small hydropower sector. It operates a mini hydro power plant in Cirompang, West Java, with a total capacity of 8 MW.

4.4.6. Technology providers

Technology provider in small hydro power value chain consists of local and global turbine producers, engineering procurement and construction (EPC) companies and consultancy companies. There are four local turbine manufacturers that have produce many turbines for projects in Indonesia and namely, PT Heksa Prakarsa Teknik, CV Cihanjuang Inti Teknik, PT Kramat Raya Sejahtera and PT Entec Indonesia (AHB, 2010). They can produce micro hydro power turbines with a capacity of up to 1 MW. Outside West Java, GIZ (2021b) reported that there are 37 local turbine manufacturers in Sumatera and Sulawesi that can produce micro hydro power turbines with high quality. While, mini hydro power turbines with more than 1 MW of capacity are supplied from global turbine producers such as PT Andritz Hydro, PT Voith Hydro Indonesia and Zhejiang Jinlun Electromechanic Co., Ltd.

4.4.7. Universities and research organizations

Research organizations and universities such as Bandung Institute of Technology, Gadjah Mada University and many other universities in Indonesia have been involved in conducting research and developing small hydro technology in Indonesia. In addition, government research institutions, including the Indonesian Institute of Sciences (LIPI) and Agency for the Assessment, Application of Technology (BPPT) and Center for Research and Development of Electricity Technology, New Energy, Renewable Energy, and Energy Conservation (P3TKEBTKE) have also been contributing to research and technology development.

4.4.8. Consumsers

Electricity consumers in Indonesia are divided into four segments: households, industries, the business sector, other sectors (i.e. government offices, social and public street lighting) (PLN, 2019b). Households is the biggest consumers with 42.25% of the total consumption, followed by industries (31,72%), the business sector (19,10%) and other sectors (6,92%). Each segment consists of several tariff types based on their consumption level and affordability. Households tariffs consist of two groups: subsidies and non-subsidies. Subsidies group is households with the consumption level of 0-451 VA and 451-900 VA. With subsidies, the electricity tariff for these groups is set at Rp 169 per kWh and Rp 274 per kWh, respectively. Non-subsidies households tariff types divided into five categories: 900 VA, 1300 VA, 2200 VA, 3500-5500 VA and more than 6000 VA. Tariff for 900 VA consumers is set at Rp 1.352 per kWh, whereas for higher power is Rp 1.444,70 per kWh (MEMR, 2021b).

4.5. Formal Institutions

Formal institutions such as laws, policies, and regulations are created to guide the government to administer Indonesia's energy and electricity sector. Based on a literature study and insights from interviews, information on the essential formal institutions as guiding principles for the electricity sector and renewable energy development is collected. In the energy sector, national energy policy is the foundation

4.5.1. Renewable energy policy

The National Energy Policy (KEN) is a formal institution that becomes a guiding principle of the strategic direction and target of the energy sector development in Indonesia. This energy policy is influenced by Indonesia's commitment to the Paris agreement to reduce carbon emission through Nationally Determined Contributions (NDCs). The President of Indonesia pledged to reduce greenhouse gas emissions by 29% on its effort and 41% through international collaboration by 2030 compared to the business as usual (BAU) projection, which is 2869 Mton CO_2 eq (National Energy Council, 2019). KEN is also driven by Sustainable Development Goals 7 (SDG 7) that aims to provide access to energy universally, increase the utilization of renewable energy and improve energy efficiency.

KEN is further elaborated in the National Energy General Plan (RUEN), which outlines the targets and actions that involve cross-sectoral actors to achieve the goals set in KEN. The targets are set as follows:

- The government aims for increasing the renewable energy mix to 23% by 2025 and 31% by 2050 in all sectors.
- The power plant installed capacity to be increased to 115 GW in 2025 and 420 GW in 2050.
- To achieve Indonesia's electrification ratio of approximately 100% by 2020.
- Electricity consumption is targeted to reach 2,500 kWh/capital in 2025 and increase to 7,000 kWh/capita in 2050.

The Sustainable Development Goal (SDG) 7 target is to ensure universal access to affordable, reliable and modern energy services. Therefore, it has indicators that must be aligned to national indicators. The alignment of the SDG 7 indicator to the SDG 7 national indicator is stipulated in President Regulation No. 59 of 2017. Furthermore, RUEN targets stipulated in President Regulation No. 22 of 2017 have also set to be aligned with SDG 7. The first indicator of the proportion of the population with access to electricity is elaborated in two targets of RUEN: increase electrification ratio to 100% by 2020 and electricity consumption to 2,500 kWh/capital in 2025. The second SDG 7 indicator of the share of renewable energy in the total energy consumption is elaborated in RUEN through the renewable energy target of 23% in 2025 and 31% in 2050 (DEN, 2019).

Since the actions to achieve these targets involve cross-sectoral actors, the government mandates the National Energy Council (NEC) as a coordinator. On the other hand, the Ministry of National Development Planning is responsible for achieving SDG 7 targets as stated in Presidential Regulation No. 59 of 2017. Under Law No. 16 of 2016, the government appoints the Ministry of Environment and Forestry as a national coordinator to achieve the carbon emission reduction target in the Nationally Determined Contribution (NDC) of the Paris Agreement (DEN, 2019).

According to Yudha & Tjahjono (2019), Indonesia deliberately aligns the national energy target with the regional energy target. The Association of Southeast Asian Nations (ASEAN) set to achieve 23.2% renewable energy in its primary energy by 2025. Currently, the utilization of renewable energy by ASEAN countries only reaches around 16.9%, meaning that more effort needs to be done to close 6.3% of the gap. The responsibility is given to every ASEAN country to contribute to closing the gap with proportional target based on demand, size of the country and the available energy potential of each country. Indonesia is the largest country in ASEAN and has a huge untapped renewable energy potential. It is expected to give the highest contribution, as much as 1.7% of the total gap.

4.5.2. Electricity Law

The "1985 Law on electricity" was the beginning of the modern era of the electricity sector in Indonesia after the independence. According to Law No. 15 of 1985, the state-owned electricity company is the only appointed party to administer electricity power business in Indonesia (An Authorized Holder Electricity Business Licence). As stated in Article 33, all commodities in the earth and water vital for people welfare, such as oil, gas, coal, essential natural resources, and hydropower, are controlled by the State. Therefore, article 33 is a legal basis for the government to administer the electricity sector through the monopoly of PLN as a state-owned electricity company. However, private parties are allowed to participate in the power generation sector as Independent Power Producer (IPP) but only limited to power generation for its own use for its business operation and selling the electricity to PLN using the Power-Purchase Agreement (PPA) scheme. Meanwhile, PLN completely controls the downstream sector, including transmission, distribution and electricity sales, with determined tariffs by the

Government (Paryono et al., 2020). PLN also takes control over the IPP to determine the capacity requirement for the power generation, the choice of fuel supply, purchasing and dispatching of electricity produced by IPP plants (Setyawan, 2014).

Following the Asian Financial Crisis, the Indonesian Rupiah was devaluated significantly against US Dollars. It led to a financial problem for PLN because a large portion of its cost elements, including PPA offtake prices, were denominated in US Dollars. On the other hand, the sales revenue was based on Rupiah (PwC, 2018). PLN renegotiated many PPA contracts with IPPs to bring offtake price down a much lower as a provision to continue the contract. Meanwhile, Many ongoing IPP projects were abandoned. This condition reduced investor confidence and crowded out private investment. PLN that suffer from the financial problem, unable to invest independently for additional power generation capacity. Therefore, the government introduced electricity Law No. 20 of 2002, which gave more opportunity to private sectors' participation in power generation and retail. Under this law, electricity tariffs can be determined by the market (PwC, 2018). However, the supporters of Article 33 challenged the idea of liberalizing the electricity sector. Two years after its implementation, the Supreme Court annulled Law No. 20 of 2002 since it was perceived as violating the Constitution (Maulidia et al., 2019). As a consequence, the Law No. 15 of 1985 was re-enacted until 2009.

In 2006, Indonesia faced a shortfall in electricity supply that cause blackouts in several provinces (Harijono et al., 2021). In order to overcome this problem, the government planned to build more power plants and implemented fast track program that consists of coal-fired power plants with a total capacity of 10,000 MW. However, PLN has a limited financial ability financial weakness after the Asian Financial Crisis 1998. Therefore, more private investments were needed to support this program. In 2009, the government introduced Law No. 30 of 2009, providing a larger space for private IPPs to invest in power generation while still maintaining PLN’s dominant position in controlling the transmission and distribution sector (Setyowati, 2020).

4.5.3. Regulation on renewable energy

MEMR Regulation No. 04 of 2020 is the most updated regulation on renewable energy tariff. It is a second amendment to previous MEMR Regulation No. 50 of 2017. It provides stipulation on tariff mechanism for electricity generated from renewable energy, including solar, hydro, wind, biomass, biogas, ocean energy and waste-to-energy. The key feature of this regulation is that PLN has to purchase all electricity produced from renewable energy power plants with an installed capacity of up to 10 MW, and PLN "must run" these power plants continuously. In contrast, larger renewable energy power plants with an installed capacity of more than 10 MW have to compete with coal-fired power plants with low cost of production (BPP) because PLN will decide from which power plant the electricity will be absorbed. Therefore, it can be problematic for large renewable energy power plants in a circumstance where the electricity is oversupplied, as experienced by some provinces during the Covid Pandemic.

In particular, mechanisms for determining the tariff for hydropower are stipulated in Article 7, covering aspects such as provisions of the electricity purchase, minimum capacity factor, tariff stipulation, Build-Own-Operate (BOO) business scheme, and procurement method. The key feature of MEMR Regulation No. 4 of 2020 and the changes that are introduced from the previous regulation are:

- The electricity purchased by PLN covers the entire range of hydro power capacity and all hydro power schemes, including river flow/waterfall, multipurpose reservoir/dam or irrigation network.
- In this regulation, no price cap is imposed for hydropower and geothermal. Therefore, it provides hydro power with more benefits than other renewable energy sources, that the maximum PPA tariff is set at 85% of the regional electricity production cost (BPP).
- The purchasing of hydro power electricity can be carried out through direct selection and direct appointment. Three tendering schemes are allowed to be used by PLN based on MEMR Regulation No. 12 of 2017: open tender, direct selection and direct appointment. Previously, MEMR Regulation No. 50 of 2017 only allows the procurement process through a direct selection mechanism. In direct selection, a limited number of IPPs registered on the Selected Provider List (Daftar Penyedia Terseleksi) can participate in the tender process by meeting pre-qualification criteria. The MEMR Regulation No. 4 of 2020 then allow direct appointment as a complement to the only direct selection mechanism that private sectors have criticized. However, the direct appointment can only be applied in specific conditions such as:
    - emergency situation or crisis in the local electricity system;
    - for purchasing the electricity excess, including from a holder of business license for electricity supply;
    - expansion project or build the additional capacity of the existing power plant;
    - for purchasing renewable electricity in a particular area that only has a single IPP candidate.
- Hydro power with an installed capacity below 10 MW (i.e,. to which small hydro power plants qualify) shall operate at a minimum capacity factor of 65%. On the other hand, hydro power plants above 10 MW operate based on the capacity factor required by the system.
- If the local Electricity Generation Cost (BPP) is higher than the national BPP, then the highest tariff is determined referring to the local BPP. If regional BPP for Sumatera, Java and Bali or other places is less than or equal to National BPP, then the tariff is determined through negotiation between PLN and IPPs.
- A Build-Own-Operate (BOO) business scheme is applied for hydropower and other renewable energy power plants. The MEMR Regulation No. 4 of 2020 revokes the Build-Own-Operate-Transfer (BOOT) scheme that was previously implemented under MEMR Regulation No. 50

of 2017, where IPPs have to transfer the power plant facilities to the PLN after the agreed PPA contract period.

4.5.4. Regulation on rural electrification

Rural electrification is a crucial government agenda because Indonesia electrification ratio has not yet reached 100%. The Ministry of Energy and Mineral Resources reported that by 2020 there are still 0.8% of Indonesia's population with no electricity access (Pribadi, 2021). This percentage equal around 2,1 million people from the total 270 million people. Although in total electrification ratio has reached 99,2%, five provinces are still below 95%, including Central Kalimantan, Nusa Tenggara Timur, Sulawesi Tenggara, Maluku and Papua (MEMR, 2021a).

The National Government pays special attention to rural electrification by laying down the principle in administering the program through MEMR Regulation No. 38 of 2016. This regulation aims at accelerating rural electrification, including remote areas, areas on the border of the country and small inhabited islands. This regulation aimed to facilitate small scale business entity to provide electricity for undeveloped rural areas. The small scale electricity provision stipulated in this regulation is defined as the system below 50 MW, including power plant, transmission, distribution, and electricity sales. The government expect to increase the participation from business actors such as private firms, local state-owned enterprises, and cooperatives in small scale electricity provision for rural areas. Therefore, the government provides incentives, not directly for business actors but as subsidies to the consumers in its operation area.

The Provincial Governor needs to submit a recommendation letter that proposes the business area eligible for small scale electricity provision using subsidies from the Central Government. The recommendation letter shall be submitted together with several required documents that cover complete technical and financial analysis. The analysis should include a detailed map of the proposed business area, local renewable energy potential study, type of the proposed power plant, business plan, local goods, services and transport cost, demand, buying power and demographic analysis.

After the submission, the technical team assigned by the Directorate General of Electricity will evaluate the document and conduct further research within 30 days of working days. Afterwards, the Director-General decide whether to approve or reject the proposal in seven working days after receiving the report.

Another regulation that supports rural electrification is regulated by MEMR Regulation No. 3 of 2014 on special allocation fund for rural electrification. This regulation includes funding available on an annual basis for supporting off-grid micro and mini hydropower implementation, rehabilitating existing power plants, and improving electricity distribution and coverage.

4.5.5. Regulation on local content

Local content regulation is first promoted through Presidential Instruction No. 2 of 2009 to increase economic growth and empower domestic industries by encouraging the government procurement of goods and services to utilize domestic products. For the electricity sector, Electricity Law No. 30 of 2009 requires Electricity Supply Business Licence holders and developers to maximize the use of local contents in terms of products and services. The specific regulation on the minimum percentage of local content for different type and capacity of the power plant is stipulated in the Ministry of Industry Regulation 54/M-IND/PER/3/2012. In particular, small hydropower projects with an installed capacity of up to 15 MW shall use 64.20% of domestic products, 86.06% for local services, and 70.76% for local goods and services combined.

The developers who fail to comply with the minimum requirement of local content will be imposed with financial and administrative sanctions. Exemptions to use import goods are allowed in three conditions. First, the goods that cannot be produced domestically. Second, the local products cannot meet technical specifications. Third, the required quantity of local goods cannot be sufficiently supplied.

4.5.6. Regulations on investment in power plants

The regulation concerning the line of investment business activity is Presidential Regulation No. 10 of 2021. It provides the lists of business that are closed to investment and lists of business that are open to private investment, including in the power plant sector. In general, as the implementing regulation of the Omnibus Law, the Presidential Regulation No. 10 of 2021 relaxes the restriction of the investment in many sectors and aims at improving the investment climate. The Presidential Regulation No. 10 of 2021 revokes Presidential Regulation No. 44 of 2016 that specify investment in the power plant sector based on the range of installed capacity, whereas the new regulation relaxes some restrictions for foreign investment and put the investment value as the conditions. The significant changes in the regulation are explained in Table 4.4.

Table 4. 4. Changes in investment in the power plant sector

Perpres No. 39 of 2014	Perpres No. 10 of 2021
Power plants with capacities less than 1 MW are only allocated to small and medium enterprises (SMEs) and cooperatives	• Power plants with capacities less than 1 MW are only allocated for small and medium enterprises (SMEs) and cooperatives. • The value of investment shall be less than 10 billion rupiahs, excluding the land and building.
• Power plants with capacities between 1 and 10 MW are available for foreign companies investment through a partnership with domestic firms. • The maximum ownership of foreign capital is 49%.	Micro and mini-scale power plant with investment value under 100 billion rupiah is categorized as priority sectors and are opened for foreign investment.

4.5.7. Water resources law

Water resources utilization play a vital role in contributing to better people life. Water is used for many sectors, including household, industrial, power generation, agricultural, fisheries, transportation and recreational activities. People need food, energy and electricity that can be fulfilled by harnessing the available water resources. In principle, the Indonesia water resources law indicate that water resources are controlled by the State and used for the greatest prosperity of the people. Due to its importance and stakeholders' tremendous interests in water resources, the law has been through several changes.

From the historical perspective, Indonesia's water resources law has experienced five generations of water resources law: General Water Regulations of 1936, Law no 11 of 1974, Law no 7 of 2004, Law no 17 of 2019 and Law no 11 of 2020. Since the Dutch colonial government era, the first water law was implemented through the “Algemeen Waterreglement” (General Water Regulation scheme) of 1936. This law was driven by several reasons: a famine in central Java caused by drought and flood, the need for irrigation to support export commodity (i.e. sugar cane), and technological innovation in hydraulics (Pasandaran, 2015).

The 1936 Law was terminated by Law No. 11 of 1974. This was characterized by the domination of the government (i.e. central and local) role in water resources management and development. The government carried out many large-scale investments in large dams, reservoirs, and irrigation networks to support the rice self-sufficiency program. Besides focusing on irrigation system development, this law also applied for provisioning drinking water, flood control, water resources conservation, operation and maintenance of water structures. In this law, the central government established the priority in governing water resources management and development. However, the utilization of water resources for hydro power generation was not explicitly covered by this law. The only related term is "energy", but it is positioned in the last priority after drinking water, domestic uses, defence, municipal uses, agriculture, livestock and plantation.

Political circumstances after the Indonesian economic crisis in 1998 influenced the passing of the Water Resources Law No. 7 of 2004. A International Monetary Fund (IMF) loan required Indonesia to reform its economic, monetary and banking sectors. Economic liberalization, one of which about water resources management, has brought up a new article on the utility right to exploit water by private sector companies. The central or regional government can permit individual or enterprises to exploit water for self-use or further business operations. Moreover, based on the World Bank study in 1997 regarding water resources, the World Bank required Indonesia to change its approach to water resource management as a requirement for further financial assistance. This urged increased allocation of water resources to other sectors rather than only to agriculture (Constitution Court, 2015). It led to the regulation of water resources utilization for energy purposes.

In 2015, Water Resources Law No. 7 of 2004 was revoked by Indonesia's Constitution Court because privatization of water resources was unconstitutional as it violated Article 33 of the Indonesian Constitution. Article 33 states that water and other natural resources shall be controlled by the State and used for the greatest prosperity of the people. Then, Law No. 11 of 1974 was reinstated until the passing of Law No. 17 of 2019.

The Java and Bali power plant labour unions submitted a judicial review to Indonesia's Constitution Court because article 19 of Law No. 17 of 2019 stated that only state-owned and/or regional-owned companies related to water resources management business are given the authority to manage water resources. However, the labour union from the power sector argues that water resources should also cover other purposes such as energy, agriculture and plantation.

4.6. Conclusions

Small hydro power technically consists of various elements from multiple engineering disciplines such as civil, mechanical and electrical engineering. Innovation of each of these technical components is done through experimentations to achieve optimum design and adapt to specific site conditions. Small hydro power in Indonesia was developed more than 100 years ago and was the primary energy source for generating electricity in Indonesia during its early development. Nevertheless, it was outcompeted with fossil fuels (i.e. coal, oil and gas) as Indonesia was the oil exporter which produces more than one million barrel oil per day in 1973 (BP, 2020). Furthermore, Indonesia has considerable coal reserves that can be used as the energy source to generate electricity, increase electricity access, job opportunity and improve economic activity. After sluggish development during the oil boom era, international donors and development agencies reintroduced small hydro power to provide electricity in rural areas in Indonesia. Many experiments had been carried out by international donors and local NGOs during the reintroduction phase, mainly in the rural electrification context. Endev (2020) reports that 286 SHP plants and mini-grid with a range of capacity from 5 to 400 kW have been installed to provide people in rural areas with access to electricity. From 1992 to 2018, IBEKA, as a local NGO, has constructed 65 SHP plants in Sumatera, Java, Kalimantan, Sulawesi and Nusa Tenggara. These plants range between 0.5 and 170 kW with a total installed capacity of 2,636 kW (IBEKA, 2021).

Apart from technical aspects, Indonesia's small hydro power sector entails a complex structure consisting of various actors interacting in multiple levels of authority, and guided by several formal institutions (i.e. laws, policies, and regulations). Cross-sectoral coordination is needed in developing small hydro power where water resources in rivers can be utilized not only for generating energy but also for drinking water, irrigation, transportation and other purposes. For example, the Ministry of Public Works and Housing responsible for regulating water management, dams, and reservoirs might have different priorities with the Ministry of Energy and Mineral Resources that interest in developing renewable energy such as small hydro power. Therefore, it is crucial to describe diverse actors related to small hydropower and formal institutions that are interdependent between different sectors comprising energy, electricity, water resources, economic and business, as it can create barriers and opportunities for small hydro power niche development.

5. Multi-level perspective analysis

5.1. Sociotechnical landscape

Small hydropower development in Indonesia is influenced by landscape factors such as climate change, energy issues, economic crises, and sustainable development agenda. However, these factors are beyond the influence of the niche actors and regime actors. This section explains landscape development that influence regime and niche level.

5.1.1. Climate change

Global organizations take the initiative to provide funding for reducing climate change impacts. For example, Green Environment Facility (GEF) and Asian Development Bank (ADB) fund projects to support developing countries to improve their quality of life, alleviate poverty, and improve environmental sustainability. Since 1990, GEF has provided a grant for Indonesia to finance projects related to climate change, biodiversity and land degradation (Maulidia & Halimanjaya, 2014). For small hydropower, in 2004, GEF supported a five years project, namely Integrated Microhydro Development and Application Program (IMIDAP) in Indonesia. This project aims to reduce GHG emissions due to fossil fuel power plant operation by promoting the implementation of micro-hydropower plants in Indonesia. Through the IMIDAP project, GEF collaborated with other actors, including the Government of Indonesia, UNDP and private firms, to co-finance the project (GEF, 2021).

From 2004 to 2008, Asian Development Bank (ADB) provided a loan for PLN to expand renewable energy consist of eight mini-hydropower plants, two large hydropower plants and three geothermal power plants in Indonesia. The objective of this project was to reduce the negative impacts of fossil fuel power plants by displacing them with renewable energy sources. The project was claimed to successfully generate additional power generation capacity from renewable energy by approximately 75 MW and reduced carbon emission equivalent to 258,550 tons per year by displacing 523.94 GWh of fossil fuel power plants (ADB, 2014). Data from World Bank (2021c) shows that electricity production from coal resources was approximately 30% of the total power generation in 1990. A downward trend to around 25% was shown until 1996 due to a dramatic increase in gas power plant capacity from 1233 MW in 1990 to 4385 MW in 1994 (Harijono et al., 2021). Nevertheless, there was a continuous increase in coal-based electricity afterwards, reaching 59% in 2019, as shown in Figure 5.1.

The climate change issue has a significant impact on Indonesia's energy policy formulation. In the Paris Climate Change Conference 2015, Indonesia committed to reducing carbon emissions by 29% on its effort and 41% through international collaboration (Yudha et al., 2021). In 2017, the Indonesian government created National Energy General Plan (RUEN) that had been aligned with Indonesia NDC in the Paris Agreement. Reducing GHG emissions by 29% in the NDC is not expected only from the energy sector but also from other sectors such as transportation and industry. Therefore, in RUEN, the government set the reduction target of GHG emission from the energy sector is 34,8% in 2025 (DEN, 2019).

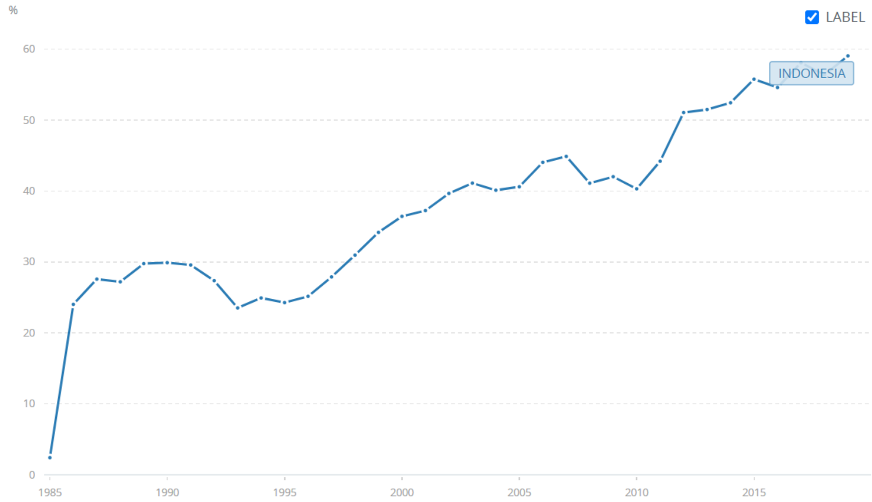

Figure 5. 1. Electricity production from coal resources in Indonesia, reprinted from World Bank (2021c)

In sum, the climate change issue as one of the landscape factors has opened a window of opportunity for small hydropower niche by removing some financial barriers, creating a network of actors and providing expertise for the project implementation in Indonesia. The climate change issue also created pressure on the regime. It encouraged the Indonesia Government to reduce GHG emissions as stated in the nationally determined contribution (NDC) of the Paris Agreement. It leads to the increasing target of renewable energy contribution to the total energy mix to achieve the emission target reduction. Therefore, the Indonesia Government is undergoing programs to utilize many renewable energy resources and put small hydropower as one of the clean energy to be developed because there is still a lot of energy potential that is still not being harnessed.

5.1.2. Population growth and rural electrification

In 1991, the population of Indonesia was 184 million people, from which only 48,5% of Indonesian had access to electricity (World Bank, 2021a). Indonesia experienced enormous population growth during 28 years, where the population increased by 46,7% to 270 million people in 2019. In terms of electricity consumption, in 1991, there was only around 178 kWh per capita. For the coming decades, it was estimated that the growth of electricity demand would increase by 13% per year. Therefore, the Indonesian government needs to increase power plant capacity to meet the demand and to avoid shortages (Meier, 2001).

In 1990, around 68,3% of Indonesian people lived in rural areas (World Bank, 2021e), where only 31,1% of them had access to electricity (World Bank, 2021b). During the 32 years of the Soeharto

Regime, the second President of Indonesia, rural electrification was one of the government priorities and put in the five years of development program plans (REPELITA) (Meier, 2001). However, the government of Indonesia face a crucial challenge to provide electricity for the whole population because the country is shaped as an archipelago that consists of many scattered islands. This condition requires significant investment costs to build the electricity grid. Furthermore, the distance between villages can be separated quite far in rural areas that often have limited road access.

In the 1990s, the Indonesian government did not have a sufficient budget to build more centralised fossil-fuel-based power plants and long-distance transmission lines to meet the demand (Meier, 2001). However, the rapid growth of the population and a large percentage of people in rural area still had no access to electricity encourage the Indonesian government to build power plants and electricity grid that can reach remote areas. Therefore, decentralize power generation was perceived as a suitable option for rural electrification. Micro-hydro is seen as a feasible option for that purpose.

5.1.3. Rural development for developing countries

Some international donors and development agencies are involved in rural development in developing countries, for example, GIZ, UNDP, and Korea International Cooperating Agency (KOICA). They carried out programs that aim to reduce inequality in human development and improve people's quality of life in rural areas in developing countries. Providing electricity access to rural areas is one of the programs carried out by international donors and development agencies. Affordable electricity access based on clean energy from locally available resources such as wind, solar and hydro is expected to improve the quality of life of people in rural and remote areas in developing countries. In general, it is also in line with the target in SDG7 to provide affordable and clean energy.

In Indonesia, GIZ and BMZ launched a Green PNPM Micro Hydro Power Technical Support Unit (MHP-TSU) program from 2009 until 2012. This program is lead by the Indonesia Ministry of Home Affairs and co-financed by German and the Netherland Government (GIZ, 2021b). A similar program has done by GIZ, namely Energising Development (EnDev) Indonesia, carried out from 2009 to 2019. It leads by MEMR and involves international donors from European countries such as the Ministry of Foreign Affairs of the Netherlands, UKaid, Norwegian Ministry of Foreign Affairs, Swedish International Development Cooperation Agency (SIDA) and Swiss Agency for Development Cooperation (SDC), led by MEMR. This program develops mini-grid in rural areas using one or two renewable energy: Solar PV and micro-hydropower (GIZ, 2021a). UNDP collaborate with a local bank in Jambi to develop micro-hydropower plant to provide electricity for isolated rural area in Jambi (Wignaraja, 2020). Another example is the micro-hydro power plant in Cipta Gelar Village West Java that KOICA has supported.

In general, these programs have a similar objective to improve human development in rural areas of Indonesia through the provisioning of electricity from micro-hydropower plants. Apart from providing grants, international donors also give technical assistance to improve the capability of the local community in operating micro-hydropower plant. According to GIZ (2021b), through the Green PNPM program, the capability of local turbine manufacturers are improved. As a result, 37 manufacturers in Sulawesi and Sumatra can produce micro-hydropower turbines.

5.1.4. The Asian financial crisis 1998

The Asian Financial crisis in 1998 was triggered by the monetary crisis in Thailand and trickled down to Indonesia and South-East Asian countries. Indonesia is the most suffered country at that time where the Indonesian currency (Rupiah) exchange against US Dollar dropped dramatically, from Rp 2400 to Rp 13,000 (Firman, 2002). According to Sadli (1998), Indonesia economic crisis was due to overborrowing and overinvestment of the private sector, banking and corporate using foreign loans. However, the foreign loans inflow was allowed with minimum prudence. The weakening of the rupiah exchange rate led to the massive foreign capital outflow of around US$ 4.3 billion compared to US$ 1.1 billion of capital inflow in 1999. The Indonesian economic crisis in 1998 was a complex phenomenon that influenced by economic factors and political factors after a long tenure of the Soeharto Regime related corruption, collusion, and nepotism, which triggered massive protest from student and people (Firman, 2002).

Indonesia experienced many years of electricity supply shortage prior to the Asian financial crisis in 1998. Hence, Indonesia opened the opportunity for the private sector to participate in the power generation sector under the new electricity law. At that moment, private IPPs developed many large-scale power plants. However, during the Asian financial crisis, Indonesia faced overcapacity due to decreasing electricity demand in the Java-Bali grid (Meier, 2001). Meanwhile, the fall in Rupiah currency exchange vis a vis to US Dollar put PLN into a financial problem because PLN had to purchase electricity from IPP under PPA contract using US Dollar and sell in Rupiah.

PLN carried out a rural electrification program through grid expansion and installed small-scale diesel power plants. However, it not last until the Asian Financial Crisis in 1998 heavily struck PLN. A financial problem faced by PLN led to rural electrification growth decreased significantly from 379% in 1997 to -80% in 2002. Then, PLN disbanded the rural electrification division in 2001, as shown in Figure 5.2 (Jayawardena, 2005).

Another alternative for rural electrification, such as micro hydropower, can be economically feasible since the energy potential is available locally without expanding the grid. Thus, the withdrawal of PLN from the rural electrification program becomes an opportunity for niche actors to actively participate in the development of micro-hydropower to provide rural electricity.

Figure 5. 2. Rural electrification trend from 1995 to 2002 (Reprinted from Jayawardena, 2005; 9)

5.2. Regime analysis

5.2.1. Network of actors

In the past, under the Soeharto regime, the Indonesian Government divided the long term development plan of 25 years into a short term plan in five years period (REPELITA). It aimed to provide electricity for all rural areas in Indonesia by the end of the 7th five-year period in 2004 (REPELITA VII). As stated in the Indonesia state policy guideline of 1998, the Indonesian Government aimed to achieve equal development throughout the archipelago, including remote and isolated areas. Although not explicitly stated, the government carried out the rural electrification program in order to achieve the objective of the state policy guideline of 1998. At that time, the energy policies and national energy programs were formulated by the National Energy Coordination Board (BAKOREN), an inter-ministerial organization. The main actor for rural electrification was the Ministry of Mines and Energy (MME) through the Directorate General of Electricity and Energy Development (DJLPE). DJLPE was responsible for coordination with other government and non-government actors such as the Ministry of Public Works, PLN, private sector, village cooperatives and NGOs (Meier, 2001).

In 2007, BAKOREN was disbanded, and the Government of Indonesia introduced the National Energy Council (DEN). DEN consists of the government side and stakeholders. Seven ministers represent the government, whereas stakeholders are represented by eight persons from academic groups, industrial groups, consumer groups, technology, and the environmental sector. DEN is chaired by the President of Indonesia dan the Vice President as vice-chairman (DEN, 2021). DEN has a crucial role in the formulation of long term energy policies. Therefore, DEN carries out decision-making in energy policies by involving various actor groups.

The Indonesian government paid considerable attention to the development of renewable energy in 2007. It was marked by the establishment of the Directorate General of New, Renewable Energy and Energy Conservation (DGNREEC) which manages the implementation of renewable energy policies, controlling, supervising and evaluating the programs related to the renewable energy sector (MEMR, 2021c). In addition to developing large-scale renewable energy projects such as geothermal and biofuel, DGNREEC also drives the development of small hydropower, solar PV, wind energy, biomass, and other new sustainable energy sources. Rural electrification program is also an essential agenda for DGNREEC, particularly by implementing micro-hydropower and solar PV.

The government mandates PLN to provide electricity for all Indonesian in an equal distribution. While at the same time, as a public corporation, PLN should also aim for profitability. With the challenging geographical condition of Indonesia that consists of 17,500 islands, fulfilling the obligation of electricity provision in remote and rural areas will be a financial burden for PLN since it is not economically feasible, even with subsidies from the government (Maulidia et al., 2019). Considering this challenge, PLN needs private sector participation to invest in power generation projects for large-scale on-grid and small-scale off-grid power plants. It leads to the formation of a network of actors at the regime level that consists of PLN, the governments, private firms, cooperatives and NGOs.

5.2.2. Rules

Indonesia experienced strong economic growth after the Asian financial crisis. GDP-constant increases continuously each year with GPD growth on average 5.26% during the period 2000 to 2019, as shown in Figure 5.3. (World Bank, 2021d). However, the strong economic growth was not accompanied by the increasing capacity of power generation. With a limited capacity of power generation and increasing demand, many PLN grid several provinces experience blackouts. This condition raised concern from President Susilo Bambang Yudhoyono, who appointed Vice President Jusuf Kalla to overcome the electricity crisis. Jusuf Kalla visited PLN head office, led a meeting on 17 March 2006 to discuss the solution to overcome the electricity crisis (Harijono et al., 2021). In order to avoid a further shortage of electricity supply, the Indonesian government needs to respond by implementing the first phase of the fast track program that aims to build 10,000 MW coal-fired power plants quickly. The coal-fired power plant was chosen because it can relatively be quickly developed, and Indonesia has sufficient domestic coal reserves. In addition, the oil price was increasing from 47.05 USD per barrel in 2004 to 67.28 USD per barrel in 2006. The gas-fired power plant was not an option because it was very difficult to get natural gas supplies at that moment (Harijono et al., 2021).

In 2015, Indonesian President Joko Widodo launched the second phase of the fast track program with a total capacity of 35,000 MW. Although this program launched at the same period when Indonesia set the target to meet the Paris Agreement objective, coal-fired power plants still contribute to the largest portion and only 25% is expected from renewable energy sources (EBTKE, 2016). The slow transformation from the coal regime to renewable energy illustrates the lock-in mechanism in Indonesia's electricity sector.

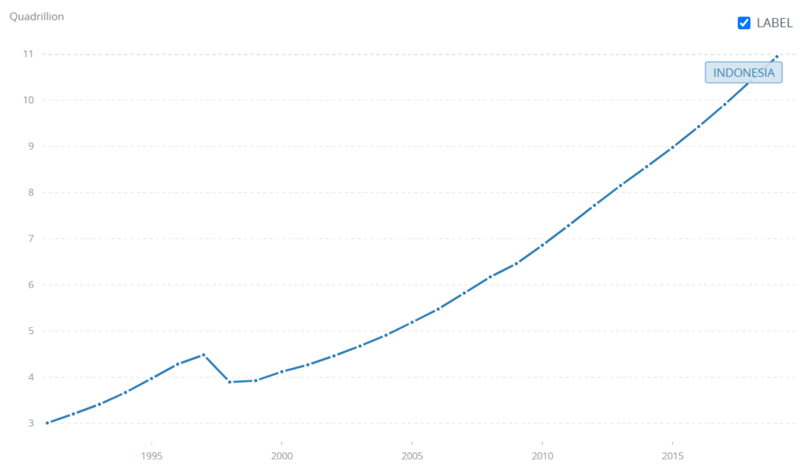

Figure 5. 3. GDP constant of Indonesia period 1991 – 2019 (Reprinted from World Bank (2021d)

The Indonesian government subsidies the electricity sector because it is related to public necessities. The subsidies are provided in two forms: direct subsidies for the consumer and subsidies for the power generation industry and the coal mining industry (Kurniawan et al., 2019). Subsidies for the consumer is implemented through providing low electricity price for the consumers below Electricity Generation Cost (BPP). Then the government pays the subsidies to PLN as loss compensation. On the other hand, subsidies for the power generation industry (i.e., PLN and IPP) is carried out by setting regulation for fix price guarantee where the coal price is set at maximum US$70 per ton regardless the fluctuating global coal price that can be higher. In addition, the government also guarantees the coal supply for domestic power plants through Domestic Market Obligation (DMO) set at 25%. In return, the government gives tax exemption, loan guarantee and preferential royalties of approximately up to US$ 1-2 per ton as subsidies for the coal mining industry (Arinaldo & Adiatma, 2019)

The subsidies regulation in the electricity sector protects coal-based power generation and thus have a detrimental effect on the renewable energy sector. Coal-based power generation is more competitive than renewable energy because the utility and coal mining sectors receive subsidies from the government that lead to a lower BPP. Furthermore, electricity supply from coal-based power generation has more significant economies of scale than renewable energy sources such as small hydropower. In other words, the more extensive power plant capacity results in a lower production cost. As a consequence, small hydropower plants have to compete with cheaper coal-fired power plants.

5.2.3. Material and technical elements

Total power generation capacity in Indonesia in 2020 reached approximately 63.33 GW, of which PLN owns 44.17 GW, and IPPs own the remaining 17.72 GW. In addition, around 1.44 GW of the power plants are operated with lease status (PLN, 2020). From the total capacity owned by PLN, around 45.9% are coal-fired power plants. Nevertheless, PLN also strives to increase the capacity of power plants from renewable energy sources, including hydropower, geothermal, solar, wind and biomass, which contribute to around 9.5% of the total power plants owned by PLN. In terms of the number of power plants, Indonesia has 6,677 power plants consist of coal-fired power plants, hydropower, gas, combined cycle gas, geothermal, solar, wind and biomass (PLN, 2020). Because of its large output capacity per power plant, coal-fired power plants with only 127 plants owned by PLN contribute to almost half of the power generation capacity in Indonesia. Of all these power plants, diesel power plants contribute the largest proportion of 5,400 units, of which 5,200 units are small-scale diesel power plants spread throughout Indonesia in 2,130 locations to reach remote and isolated areas.

5.3. Conclusions

Several landscape factors have influenced small hydro power development in Indonesia. In the beginning, international donor and development agencies were driven by energy (electricity) poverty issues took initiatives to develop micro hydro power plants in rural areas in Indonesia. At the same time, the Government of Indonesia has to provide electricity access to all Indonesian citizens in the archipelago. However, the Asian Financial Crisis in 1998 caused financial constraints for PLN to sustain the rural electrification program. The regime’s weaknesses in financial aspect and infrastructure had opened the opportunity for niche actors to develop the small hydro power niche to support the rural electrification program. Recently, the climate change issue and Indonesia's commitment to the Paris Agreement set in Nationally Determined Contribution (NDC) influence policymakers to determine a renewable energy target in national energy policy. Small hydropower is one of the renewable energy sources targeted to grow due to its large potential.

At the regime level, the power generation sector is dominated by coal-fired power plants with an ongoing implementation power plant project with a capacity of 35 GW. Furthermore, the coal regime is stabilized through a cross-subsidies policy between coal-based power plants and the coal mining industry. Although private firms are given room to invest in the power generation sector, the transmission and distribution sector is still under the monopoly of PLN. The government also have control over the electricity sector in Indonesia. These factors present the regime’s selection pressures on the small hydro power niche.

6. Niche development

This chapter aims to analyze niche processes using the concepts of Strategic Niche Management and present barriers and opportunities based on insights from niche development analysis. The analysis is derived mainly from the information collected through semi-structured interviews with diverse actors in small hydropower in Indonesia.

6.1. Network formation

6.1.1. Composition

In 1988, there was a project was a collaboration between GTZ (Deutsche Gesellschaft fur Technische Zusammenarbeit GmbH) and SKAT (the Swiss Center for Technology Management). GTZ collaborated with SKAT to get technology transfer service and consultancy and implement micro hydro power plants in 20 countries in the South, including Indonesia. In 1991, GTZ launched a program called the GTZ-MHP (GTZ Mini Hydropower Technology Dissemination Program). This project was a bilateral project between the German and the Indonesian government with the objective to implement micro hydro power technology in rural areas in Indonesia. The Government of Indonesia was represented by the Ministry of Mines and Energy (MME) through the Directorate General for Electricity and Energy Development (DJLPE) and the Ministry of Cooperatives. This program trained local engineers such as Ir Kusetiadi Raharjo (PT Heksa Prakarsa Teknik founder) and his colleagues and sent them to visit a turbine manufacturer SME in Switzerland. As a result, this program increased local engineers' capability.

As there were still limited local engineers with expertise and experience in the development of micro hydro power, the GTZ-MHP program focused mainly on technology transfer. A West Java-based NGO, Yayasan Mandiri, was appointed as the local technical counterpart. To address business aspects, some engineers from Yayasan Mandiri then established a private company, namely PT Hidropiranti Inti Bakti Swadaya (PT HIBS). Between 1991 and 1996, through this program, 40 micro hydro power plants were built with technical assistance from GTZ-MHP. Through this program, local turbines had also been exported to projects in Africa (Meier, 2001). Between 1996 and 1998, local private companies that established during the GTZ-MHP program independently involved in 40 projects funded by DJLPE or the Ministry of Cooperatives without comprehensive technical support from GTZ-MHP. However, many failures were experienced by these projects. Meier (2001) argued that these projects were carried out with too much focus on transfer technology.

In addition, between 1990 and 2000s, several micro hydro power projects in West Java were supported by international donor and development agencies in collaboration with local NGOs (GEF, 2021). For example, JICA partnered with IBEKA to develop micro hydro power plants in Cicamet and Citalahab. Micro hydro power in Ciganas was developed through collaboration between GEF and IBEKA.

Between 2009 and 2019, GIZ commisioned a project called Energizing Development (Endev) to develop mini-grids based on micro hydro power and solar PV for rural areas in Indonesia. This program was supported by six donor countries including the Netherlands, Germany, the UK, Norway, Sweden and Switzerland, and lead by DGNREEC. During this period, Endev Indonesia and DGNREEC has developed 250 micro hydro power plants through out Indonesia (EBTKE Public Relations, 2020)

International collaboration in research and development was also carried out in 1998 between Stuttgart University, Entec AG and GTZ to conduct a laboratory test of Cross-flow turbine T-14. This activity also involved local engineers. Niche actors actively shared knowledge through training and courses during the re-introduction period after 1991. Eventually, the capability of local engineers increased, and afterwards, they became the trainer in many micro hydro training courses in Indonesia and other developing countries. In addition, some of them became key players as the owner of turbine manufacturers, consultants and NGO leaders.

Due to the proximity of the location among actors and their social network, the niche actors that reside in Bandung established Bandung Hydro Association (AHB). It consists of company owners and professionals in micro hydropower such as surveyor drafters, engineers, operators, manufacturers, researchers and educators. The objective of AHB is to increase the capability of its member and reliability of micro-hydropower technology through sharing knowledge and information dissemination to other stakeholders. The member of AHB including key players turbine manufacturers in Bandung, West Java, such as PT. Heksa Prakarsa Teknik, CV. Cihanjuang Inti Teknik, PT Kramatraya Sejahtera, Yayasan Mandiri and other smaller local manufacturers.

After GTZ-MHP program in the 1990s, other actors from landscape, regime and niche level attracted to get involved in micro hydro power development. In general, the composition of actors involved in small hydro power in West Java is presented as follows:

1. International donors and development agencies
2. Central government (MEMR, the Ministry of Finance, the Ministry of Public Works and Housing and the Ministry of Cooperatives and SMEs)
3. Provincial government (Energy and Mineral Resources)
4. PLN, private IPPs, local-owned company (BUMD) and cooperatives.
5. Local NGO (IBEKA, Yayasan Mandiri)
6. Local turbine manufacturers (PT. Heksa Prakarsa Teknik, CV. Cihanjuang Inti Teknik, PT Kramatraya Sejahtera) and global turbine manufacturers
7. EPC and consulting companies
8. Research Institute and universities
9. Rural communities

6.1.2. Alignment

From the previous description, the composition of actor-network in West Java seems complete. However, the different interests of actors might lead to challenges when these actors need to collaborate in projects. A government official mentions,

"There are always challenges in collaboration, and each actor has different interests. We, as the government, act as regulators, research and development. PLN as the SOE plays the role of executor of electricity development. Other actors give their inputs for policy and regulation. To overcome these challenges, we as the government set the common targets that the State must achieve. So that different interests of various actors can be aligned to achieve the ultimate goal." (Pranoto, 2021)

At the central government level, actors under the MEMR collaborate with internal and external actors. Internal collaborations are carried out with other directorates such as the Directorate General of New and Renewable Energy and Energy Conservation, the Directorate General of Electricity, and the Human Resources Development Centre. In terms of external cooperation, MEMR collaborates with the Ministry of Public Works and Housing (PUPR), which has data on river and water resources, to conduct the study of hydropower potential. MEMR also works with hydropower associations in Indonesia to gather input from experts. Collaborations are also carried out together with PLN (Pranoto, 2021). PUPR is responsible for regulating water management, dams and reservoirs might have different priorities with the Ministry of Energy and Mineral Resources that interest in developing renewable energy such as small hydro power. However, in 2016, PUPR claimed to provide 18 reservoirs for small hydro power plants through a land leasing scheme (Perdana, 2016).

Professionals and activists in the micro hydro power sector in Bandung West Java established Bandung Hydro Association. AHB was quite active in conducting training for professionals in micro hydro power and as a forum for communication between members. However, AHB is no longer quite active in organizing training activities.

"..In the past, the AHB was quite active, an association that brought together micro-hydro professionals. We often held training. There are firms that are located in Bandung besides PT Heksa. There was PT Kramat, CV Cihanjuang and other smaller companies that supported government projects." (Raharjo, 2021).

According to Raharjo (2021), it was caused by two factors. First, a prominent AHB member developed micro hydro power individually without collaborating with other AHB members. Second, a corruption case involving officials from the Ministry of Energy and Mineral Resources in 2012 related to a micro hydro power project (KPK, 2012). Raharjo (2021) further indicates that this issue created fear among micro hydro developers to be involved in government projects. It is also influenced by the character of micro hydro projects that involve many civil works prone to fraud in terms of specifications and quantity of materials that are subject to be audited by government auditors when the project is completed.

Afterwards, there was a tendency that developers choose to develop Solar PV because the panel installation is more straightforward and has clear specifications when it comes to the auditing process by the government auditor.

6.2. Shaping expectations

6.2.1. Exogenous factor

Exogenous factors influence actors' expectations from outside the niche. These factors include landscape development such as low electrification ratio and climate change, regime condition, and development of other niches. In the early phase of the reintroduction of small hydro power in Indonesia, niche actors expected micro hydro power plant implementation to increase the electrification ratio in rural areas in Indonesia (Raharjo, 2021). In 1991, the electrification ratio in Indonesia was only about 48.9% (World Bank, 2021a). With a total electrification ratio in Indonesia of around 99% in 2021, as shown in Figure 6.1., actors expect small hydro power can be implemented in rural areas in the Eastern Region of Indonesia that still have no access to electricity (Raharjo, 2021).

The need to mitigate climate change influenced the formulation of energy policy with the increasing renewable energy target. It created positive expectations among niche actors that small hydro power can contribute more to the total energy mix (Interviewee 2, 2021; Pranoto, 2021; Wijayanti, 2021). In addition, small hydro power plants are also expected to replace small-scale diesel power plants (Tasrif, 2021). However, niche actors perceived that current regulations are insufficient to provide a supportive condition for small hydro power to grow. Therefore, niche actors expect the government to create supportive regulations, such as the feed-in tariff and business schemes that are more attractive for private IPPs. Many niche actors share this expectation through regular meetings with stakeholders, including the government, PLN, private firms and associations (Adistira, 2021).

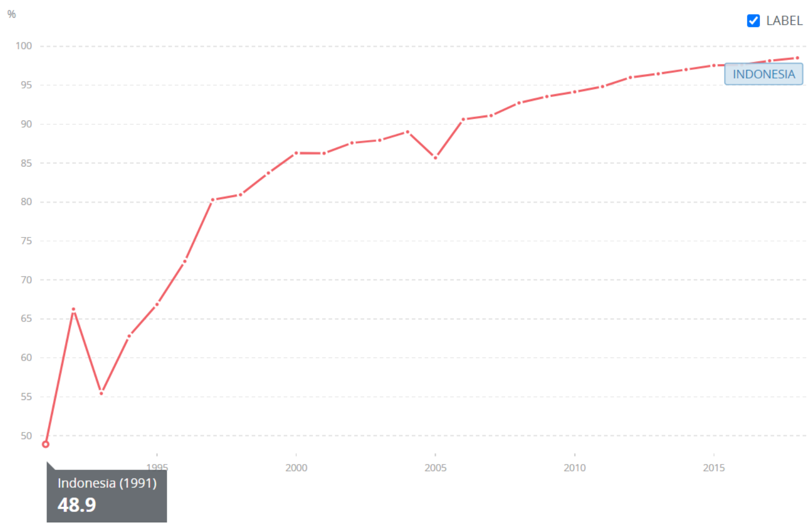

Figure 6. 1. Indonesia electrification ratio, reprinted from World Bank (2021a)

The awareness to increase the utilization of renewable energy and rural electrification has led other renewable energy technology niches such as Solar PV, wind power and biomass to grow. On the one hand, other niches are perceived as competitors for small hydro power as they compete in cost and ease of installation. On the other hand, small hydro power niche actors expect other niches to be deployed together with micro hydro power plants under a mini-grid system (Raharjo, 2021).

The electricity regime has experienced the electricity oversupply condition in Java since 2018, as indicated in Figure 6.2. Furthermore, oversupply condition is not only occurred in Java but also in North Sumatera Province. In North Sumatera, 54 MW of small hydro power plants were negotiated by PLN to lower its production to 35 MW due to the oversupply condition (Petriella, 2020). Considering this regime factor, niche actors expect that PLN can maximally absorb the electricity production from small hydro power plants because it has a relatively competitive price compared to coal-based power plants. In addition, future small hydro power projects should be implemented in provinces outside of Java that still have lack electricity supply (Raharjo, 2021).

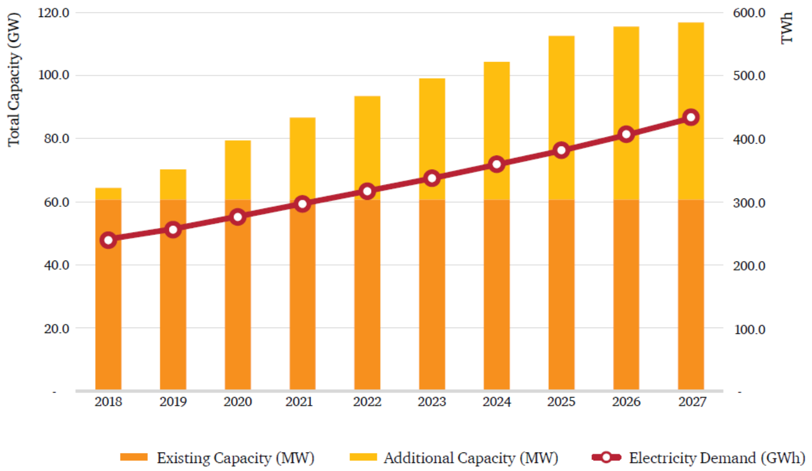

Figure 6. 2. Electricity demand and power plant installed capacity 2018 – 2027 (Reprinted from PwC 2018; 16)

6.2.2. Endogenous factor

Successful project implementation in West Java and Sumatra had increased the capability of local engineers and the reliability of the power plant. Niche actors collaborated in a micro hydropower community that shared their positive expectations also influenced and attracted the government to get involved in niche development. Through the Directorate General of Electricity (DGE), the government became more actively involved in micro-hydropower projects by providing government grants (Raharjo, 2021; Hindrakusuma, 2007). As per 2006, with positive expectations shared among niche actors, increased capacity of niche actors and active government participation, micro-hydro power experienced a booming period. The founder of PT Heksa Prakarsa Teknik, Ir Kusetiadi Raharjo, mentioned that his company's production capacity had increased dramatically in the booming period. The production increased from 6 turbines per year during the pioneer period (1992-2005) to 50 turbines per year in the booming period circa 2009.

The technical capability program funded by international donors has resulted in more than 350 small hydro power engineers, technicians and project developers (Tenenbaum et al., 2018). With more than three decades of experience and many local professionals, niche actors have a positive expectation that the local micro hydro power industry can grow further, not only supplying micro hydro turbines for the domestic market but also for overseas (Raharjo, 2021). Local turbine manufacturers have shared this expectation, and good quality of expectation has been proven by increasing demand. Locally made turbines have been exported to many countries in Africa (i.e. Cameroon, Ethiopia, Madagascar, Mozambique, Tanzania, Uganda and Zaire), Asia (i.e. Laos, Malaysia, Philippines, Nepal) and Europe (i.e. Germany, Switzerland and the United Kingdom) (Tenenbaum et al., 2018). However, due to the limited capability of local turbine manufacturers, the development of the larger size of turbines (i.e. mini hydro power turbines) is not at the same level. Therefore, local turbine manufacturers expects that the government pays attention to develop this mini hydro power industry by providing funding to build the production infrastructure (Raharjo, 2021).

During the pioneering period, niche actors collaborated in the GTZ-MHP project. Niche actors involved include GTZ, the Directorate General of Electricity, local government, local turbine manufacturers, small private firms, non-government technology institutions, and local NGOs. They focused on a stand-alone and off-grid scheme of micro-hydro power generation. After successful implementations in some rural areas, niche actors shifted their expectations. Niche actors hoped to sell the electricity to a state-owned electricity company through an on-grid scheme (Hayton, 1997). Since PLN has gradually extended the grid to rural areas, this usually led to four conditions: the existing micro hydro power plant was abandoned, it continued to operated side by side with the PLN grid, sold the excess output or all the output to the PLN grid (Tenenbaum et al., 2018). With these alternative outcomes, the developers expect the ideal condition that the consumers stay with the micro hydro power plant and sell the excess output to PLN at a competitive price (Anugrah, 2021; Interview 1, 2021; Purnama, 2021). Alternatively, the developers expect that the government can provide funding to develop small businesses to be supplied by the micro hydro power plant to avoid the power plant from being abandoned.

Based on interviews with niche actors and stakeholders, the present study reveals that expectations changed over time due to dynamic internal niche and external factors. Actors also have different expectations, as described in the following part.

6.2.3. Internal expectation

Niche actors carry different expectations. Therefore, this thesis presents diverse niche actors' expectations.

State-owned electricity company (PLN)

When asked about expectations, a manager at PLN claimed that mini-hydro power should be maximally harnessed because it has some advantages. First, there is still a great untapped potential that can be used at a relatively lower cost. Second, the technology has been widely implemented and has matured. Third, compared to the intermittent character of solar PV and wind, mini-hydro has the advantage of up to 24 hours of power stability as long as the water continues to flow and thus can serve as a baseload power plant. Finally, it is suitable for remote areas that have not been reached yet by the electricity grid. Still, the economic viability between extending the existing grid and build the off-grid mini-hydropower plant needs to be considered (Interviewee 2, 2021).

Private IPP companies

The long and complicated process to acquire permits makes private developers less interested in developing mini-hydro power. The permits required to be completed, for instance, land usage permit, investment principle license, environmental, water resource utilization, river border utilization, approvals from the local community, permit from security officials, and other permits (Saing, 2021; Suryanto, 2021; Wijayanti, 2021).

One of the respondents argued that the mini-hydropower market would be difficult to grow in the future due to the crucial obstacle: financial barriers. The main financial barrier is the difficulty of obtaining funding from banks. Banks' perception of risk in renewable energy projects is due to a lack of capacity to cope with this sector and the changing nature of government regulation (Setyowati, 2020). As a result, banks are reluctant to give loans with longer tenor and impose burdensome collateral. In addition, the bank has had bad experiences with developers of mini-hydro projects where they only aimed to win a power purchase agreement (PPA) contract and use it as a marketable portfolio (Raharjo, 2021; Suryanto, 2021). They simply act as brokers that acquire permits and then benefit from selling PPA contracts to other companies. This action leads to financial institutions' distrust of mini-hydro developers. Since then, PLN created a regulation requiring the awardee of the PPA contract must be a private company with previous experience working on mini-hydro projects. Thus, new entry companies willing to involve in mini-hydro development are not eligible to do so (Suryanto, 2021).

Banks' perception of the risk of investing in renewable energy inflicts financial barriers to IPPs who sincerely want to develop mini-hydro power plants. This issue is coupled with high risk due to technical and social aspects that may happen during the mini-hydro project. As a result, banks implement a turnkey project financing scheme where the funding will be disbursed after the developer completes the project by first using its own funding source (Interviewee 3, 2021; Suryanto; 2021). Therefore, it is counterproductive for small companies to participate in mini-hydro development in Indonesia unless they create a consortium that involves a large company that can provide the capital (Interviewee 3, 2021; Raharjo, 2021; Suryanto; 2021).

Global Technology Suppliers

Given that micro hydropower with small capacity is considered less commercially viable, global technology suppliers decided to focus more on turbines with larger capacity for both mini-hydro and large hydro sizes. One of the global companies operating in Indonesia sees the business of providing technology for large hydro as more commercially promising. It is seen as having business certainty where the company supplies its technology directly to PLN as a customer (Wijayanti, 2021).

On the other hand, mini-hydro business is generally run by private sector firms is considered to have many problems, one of which is the problem of feed-in-tariff uncertainty. Changes in tariffs often occur following the change of ministers in office, while the term of office may last for a short time due to the dynamics of political factors, causing difficulty for private firms to obtain solid economic profitability of the investment (Suryanto, 2021; Wijayanti, 2021).

The process of managing permits and other legal issues may last for a long period to win a power purchase agreement contract. Suppose it occurs over more than a year. In that case, a predetermined economic calculation is subjected to change in the following year due to change economic variables such as currency, interest rate and feed-in-tariff. The bank may not approve the loan that has been proposed by a project developer if the economic variables change lead to unfeasible IRR and NPV value due to regulation changes during a particular period (Suryanto, 2021; Wijayanti, 2021). Furthermore, economic uncertainty caused by regulation changes makes mini-hydro sector unattractive for global technology suppliers because a project contract between developer and supplier that has been agreed need to be adjusted accordingly (Wijayanti, 2021).

Local Turbine Manufacturers

In terms of technology, there is no doubt about the ability of local manufacturers to build micro-hydro turbines. It had even experienced a boom period between 2006 and 2015. However, since 2017, there had been a significant decrease in turbine demand for domestic micro-hydro projects. Therefore, the local turbine manufacturer currently expects more global demand from Africa, Pakistan, Nepal, Bangladesh, and Japan. In many ways, it was influenced by corruption of village electricity procurement involving MEMR officials and many fraud problems that had occurred with civil works contractors (Raharjo, 2021). Therefore, it raised a hesitation from developers to do the business related to the micro-hydro sector, which was considered risky.

In terms of the technology preference, pump-storage hydropower (PSH) is more suitable to be further developed as a power plant as well as to overcome floods that often occur in Java. (Raharjo, 2021). The existence of other renewable energy technologies such as solar PV and wind power might be perceived as competitors for the small hydro power niche. However, a local turbine manufacturer expects that small hydro power can be integrated with PV and wind with the support of battery storage technology to overcome the intermittency problems of PV and wind power (Raharjo, 2021).

The local turbine manufacturer has not expanded its production towards mini hydro power due to limited production infrastructure to produce turbines above 1 MW. There is also strong competition with established global producers. In addition, the process to win a power purchase agreement for mini hydro power is considered quite complex (Raharjo, 2021).

Central government

Currently, Indonesia has 5200 small-scale diesel power plants spread throughout Indonesia in 2130 locations to reach remote and isolated areas. The government planned to replace 5200 small-scale diesel power plants with renewable sources (Tasrif, 2021, 35:10). Therefore, it is necessary to map local energy potential in these locations. The MEMR expects renewable energy sources such as micro hydro power plants to replace small-scale diesel power plants.

A researcher at MEMR asserted that the challenge of developing small hydropower is the supporting infrastructure such as road access and electricity grid that might not be available yet. The potential locations are generally located in remote and undeveloped areas. Therefore, to further implement small hydro power, the supporting infrastructures also need to be developed, which might require a significant investment.

"Each region has different challenges in developing new and renewable energy. The speed of NRE utilization must be balanced with the speed of network infrastructure development. The potential locations for new and renewable energy are generally located in remote areas, such as the small hydro potential, often located in the upstream parts of the river that commonly have sufficient head. These locations are generally far from access roads and the electricity grid" (Pranoto, 2021).

Provincial government

The provincial government perceives that the regulation related to government grants has a weakness. Based on the regulation, the provincial government is only authorized to execute micro-hydro development projects starting from planning, tender, and construction. Meanwhile, after the project completion, the power plant will be fully handed over to the local community who received the grant, whether for business entities, cooperatives or community groups. Furthermore, the provincial government does not have the authority to be involved in the operation or maintenance of equipment damage at any time. Indeed, before project construction, the provincial government has provided training for the local community to operate and maintain a micro hydro power plant. In general, local communities are able to operate and conduct minor maintenance of the power plants (Interviewee 1; 2021).

However, there are possibilities that the power plant needs major maintenance due to natural disasters such as landslides and floods. In many cases, the local community cannot handle a major breakdown because it requires a high cost. In this case, the local community will propose a revitalization plan to the provincial government. To revitalize the power plant, the government should allocate the budget for next year and conduct an open tender mechanism that cannot be completed in a short time. Therefore, the provincial government expects that the central government change the regulation regarding government grants so that in case of a major breakdown, the provincial government can immediately provide funding for the local community (Interviewee 1; 2021).

NGOs

The government's ability is limited in providing electricity to the community, especially for rural electricity, so the community's active role is needed considering there is a lot of energy potential available locally. In order to achieve energy democratization, the opportunity needs to be given to the rural communities to provide energy for themselves independently. Therefore, a director of a local NGO expects the government to play a role as a grantor and facilitator to develop the ecosystems and the supporting regulations to empower local communities. On the other hand, NGOs' role is to provide technical assistance for the local community to operate and maintain a micro hydro power plant and use it for productive purposes to drive the economy of rural communities (IBEKA, 2021).

Local residents

Five informants who have been involved actively in rural electrification argue that the community welcomes small hydro power projects, especially in areas that do not have access to electricity. Local people expect that they can improve their life quality with electricity from micro hydro power plant. Initiatives may also come from community groups who need electricity to build their micro-hydro power plants independently by leveraging village funds (Pranoto, 2021).

However, there are also some locations where there are problems with land acquisition and where land ownership status is customary land. Problems can arise when the land acquisition of customary land has been completed both with the indigenous leader and administratively with the government, but still later leave problems. It turns out that there are still some members of the indigenous people who feel entitled to the land and oppose the land acquisition. It is a tough challenge for private companies to resolve the conflict (Saing, 2021). In some instances, indigenous people may also impose fines on project implementors if there are things that are contrary to local customs regulations. Saing (2021) recounts his experience related to the fines imposed by indigenous leaders because his company did particular project work without the permission of indigenous leaders.

Saing (2021) mentioned that the government had supported them with data and administrative matters concerning this customary land. However, active involvement from the government is still expected when the company conduct negotiations with indigenous leaders.

6.2.4. Conclusions

The expectation of niche actors has been influenced by exogenous factors such as low electrification ratio, the need to mitigate climate change, the electricity regime condition, and other niches' development. The low electrification ratio has played a significant role and motivated international donors and development agencies to introduce micro hydro power in Indonesia, increasing the adoption of micro hydro power plants. In addition, the climate change issue has raised the government's awareness to increase the utilization of renewable energy. This factor has positively influenced niche actors to develop small hydro power. They share a common expectation that the contribution of small hydro power can be increased for rural electrification. In addition, PLN is expected to absorb all electricity production output from small hydro power plants. The existence of other renewable energy niches also shifts niche actors' expectations that micro hydro power can be supplemented with solar PV or wind power within a mini-grid system.

Among endogenous factors, the increasing local engineers' capability to build locally made turbines has increased the expectation of niche actors that Indonesia has all the capacity to meet both domestic demand and overseas. Successful experiments are the endogenous factor that has attracted other actors outside the niche to be involved in micro hydro power development. As a result, the central and provincial governments provided more grants to develop small hydro power plants, while international development agencies provided technical support in West Java. In addition, they collaborated with local NGOs and shared common expectations that micro hydro power plants can drive the economy in rural areas and alleviate poverty in rural areas.

Many stand-alone micro hydro power plants have been successfully implemented in rural areas. On the other hand, the PLN grid gradually reached rural areas. This factor changed the expectation of niche actors that micro hydro power plants should be developed as an on-grid power plant, feed into the PLN grid. However, micro hydro power with a capacity lower than 100 kW is not attractive for private sector companies because it is not commercially feasible under the existing tariff regime. Therefore, this type of power plant will only be suitable as a project for capacity development for rural communities using government grants, international donor grants, and fundraising from CSR and charity. In addition, private companies share negative expectations toward the future of mini hydro power plants because there is a financial and regulation barrier. Negative expectations also emerge from local turbine manufacturers toward the future of micro hydro power because of a decreasing trend of domestic demand since 2017.

The central government expects micro hydro power plants and other renewable sources to replace 5200 small scale diesel power plants in Indonesia. While the provincial government is still actively involved in micro hydro power development and provide grants, the current regulation related to project grants has a weakness where the community or rural business entities can not finance the major maintenance cost. In the future, PLN will continue to develop renewable energy, including small hydropower and reduce fossil power generation projects due to limited funding from financial institutions that no longer can provide support for fossil fuel projects but only green financing.

6.3. Learning processes

In this section, seven aspects of learning are explained, including learning the technical development and infrastructure, policy and regulations, environmental and societal impact, user context development, industrial development, energy potential and business models.

6.3.1. Technical development and infrastructure

At the beginning of the reintroduction phase of SHP, some projects were carried out to transfer technology from donor countries to targetted countries, for instance, installing electromechanical components from Siemens (Raharjo, 2021). However, GTZ argued that only installing technology from overseas to Indonesia will not effectively facilitate the diffusion of small hydropower technology. Therefore, GIZ adopted a different method that focuses on the capacity building of local people to produce turbines using local resources. Some engineers graduated from the Bandung Institute of Technology (ITB). They were trained and sent to visit a small scale turbine manufacturer in European countries to learn how small and medium enterprises produce turbines (Raharjo, 2021). Later, the well-trained engineers by GTZ and SKAT established their local turbine manufacturers, consultant and construction companies in Bandung, one of which is PT. Heksa Prakarsa Teknik that was established by Ir. Kusetiadi Raharjo. He asserted that GTZ successfully built the capacities of local engineers by training, workshop and company visits in Switzerland:

"I was lucky that GTZ provided me with a great opportunity to visit SMEs that produce small turbines in Switzerland, discovering that the owner directly hands on the welding and manufacturing process. They built small Pelton turbines with a capacity of around 5 kW and installed them in an agricultural area in the Alps. It later inspired me to build my own company from zero." (Raharjo, 2021)

A program sponsored by Swisscontact, namely Small Metal Enterprise Development Program, also played a significant role in increasing the capability of local metal workshops. As a result of this program, several local workshops were able to manufacture turbines for micro-hydro power (Rahardjo, 2007).

According to Raharjo (2021), micro hydro power niche experienced significant growth after 2006. It was indicated by the increasing number of turbines produced by PT Heksa Prakarsa Teknik. It built on average 35 turbines per year between 2006 and 2009, compared to 1992 to 2000, which was only five turbines produced per year on average. PT Heksa Prakarsa Teknik, currently has a 4800 m^2 turbines machinery workshop and office and 40 employees, with an average production capacity of 35 turbines per year.

Turbine efficiency improvement

Efficiency is the crucial issue in small hydropower where hydrostatic pressure must be converted efficiently to kinetic energy to turn the turbine dan generator, which is finally converted into electricity. Therefore, research and development have been directed to increase turbine efficiency. According to Raharjo (2021), as a local turbine manufacturer, he contributed to improving Turbine T12 that performed below the expected efficiency. When tested by SKAT and GTZ in Hongkong and Uganda in 1995, the efficiency was only around 60%. Then research fund was allocated to produce a T15 turbine that has an efficiency of around 76%.

In short, after two decades of the learning process, PT. Heksa Prakarsa Teknik has improved production technique and using a larger CNC machine to increase production size and capacity. Now, local turbines made in Bandung have been exported and installed in many countries.

Interconnection study

Many aspects have been learnt by mini hydro power developers in Indonesia, including hydrology and geodetic engineering in the planning stage to the design stage, which includes civil, mechanical and electrical disciplines. Nevertheless, one thing becomes quite an important lesson related to interconnection studies at an early stage before the start of the project. Many projects have been successfully built up to the operation. However, electricity production is not absorbed as expected because interconnection studies are not conducted properly in the early stages of project planning. It is because data related to demand and interconnection data are not appropriately provided by PLN. In addition, consultants appointed by the IPP are too optimistic in presenting the results of interconnection studies, when in reality, electricity production can not be absorbed in the future.

Problem-related interconnection study has been shared among private firms that experienced the same. Some mini-hydro IPPs in west Sumatra planned to collaborate to create substations connected from several mini-hydropower plants to interconnect to high voltage networks. Still, this plan will be constrained by considerable costs, while PLN certainly does not want to be burdened with the cost of interconnection.

6.3.2. Policy and regulations

Investors see no certainty in terms of policies and regulations regarding renewable energy. Policies and regulations often change with the change of the ruling regime and the change of ministers (Interviewee 3; Suryanto, 2021; Raharjo, 2021; Wijayanti, 2021). For example, the regulation of the Minister of Energy and Mineral Resources on the utilization of renewable energy sources for electricity supply has undergone several changes over the last five years. In terms of business model, at first, Build-Own-Operate (BOO) business scheme was applied, and later under MEMR regulation no 50 of 2017, it changed to Build-Own-Operate-Transfer (BOOT) scheme. In 2021, the regulation was amended by MEMR regulation no 4 of 2020, altering BOOT back to the BOO business scheme.

The BOOT scheme is a reflection of nationalism that has been indoctrinated and formalized in Article 33 of the Indonesia Constitution 1945 (Interviewee 3, 2021). It is stated that all commodities in the earth and water vital for people welfare, such as oil, gas, coal, essential natural resources, and hydropower, are controlled by the State. This principle supports the monopoly in the electricity sector in Indonesia by PLN. The opposite is the BOO scheme where it gives opportunity to the private sector to own electricity asset. Since BOOT is not attractive for the private sector, it received a lot of criticism and opposition from the private sector, which may decrease private investment into the small hydropower business (Interview 3, 2021; Suryanto, 2021; Wijayanti, 2021).

Similarly, in another regulation regarding the list of businesses that are closed and open to private investment, previously, the proportion of foreign capital in small hydropower project is limited to 49%. In order to improve the investment climate, the Presidential Regulation No. 10 of 2021 revoked Presidential Regulation No. 44 of 2016 so that mini-scale power plant with investment value under 100 billion rupiah is categorized as priority sectors and are opened for foreign investment.

In the end, the government learned that achieving the renewable energy target requires participation from the private sector. In contrast, what has been learned by investors then is the uncertainty of regulations in the past five years that making them hesitant and full of caution in deciding to invest in small hydropower (Interviewee 3, 2021).

Respondents from IPPs mentioned that many regulations, licenses, and permits need to be completed for a mini-hydropower plant project (Interviewee 3, 2021; Saing; 2021; Suryanto, 2021). However, knowledge related to regulation and licensing that must be fulfilled is not shared with the IPP, so they have to find their own way to take care of it (Interviewee 3, 2021; Suryanto, 2021).

Table 6. 1. Regulation, license, permits required for small hydropower projects (reprinted from Hanung, 2018)

No.	Institution	Regulations, license and permits
1	Investment Coordinating Board	• Capital Investment Registration • Granting facility of import duty
2	Ministry Energy and Mineral Resources	• Electricity Supply Business Licence (IUPTL) • Import plan
3	PT. PLN (Persero)	• Procurement (tender/ direct selection/ direct appointment) • Letter of Intent • Power purchase agreement
4	Ministry of Finance	• Business Viability Guarantee Letter
5	Ministry of Agrarian Affairs and Spatial Planning / National Land Agency	• MAASP Regulation no 15 of 2018 on technical consideration for land affairs (Land Utilisation Permit)
6	Ministry of Environment and Forestry	• MEFF Regulation No P.27/Menlhk/Setjen/Kum.1/7/2018 regarding Guidelines on Forest Area Borrow-to-Use Permit • Environmental impact management analysis (AMDAL)
7	Ministry of Transportation	• Special Port permit and navigation permit
8	Coordinating Ministry for Economic Affairs	• Offshore loans approval
9	Ministry of Labour	• Permits for employment of foreign workers
10	Ministry of Public Works and Public Housing	• Permit for dam construction

6.3.3. User context development

There was a shift in the use of electricity in rural areas. In the early stage of experiments, electricity from micro hydro power plants was used by households for consumptive purposes to power light bulbs, televisions, radios, tape recorders and water pumps. Micro hydro power plants also contributed to supply public facilities in rural areas such as schools, village health centres, village halls and mosques. However, niche actors such as local NGOs learnt that micro hydro power should also be used for productive purposes such as agro-processing, cassava mill, coffee bean factory, ice production, small restaurant and tailor shop. This approach is important to drive the economy of the rural communities, open job opportunities and alleviate poverty. The productive use of the electricity can also protect it from the penetration of the PLN grid when it comes to the rural area where a micro hydro power plant has already existed.

The presence of the PLN grid might have an impact on user preference, especially when the electricity supply from PLN is more stable without connectivity problems. Micro-hydro power plant users are more likely to choose electricity from PLN because they no longer need to manage the power plant themselves (Anugrah, 2021; Interviewee 1, 2021; Purnama, 2021). Hence, the local community switch to the PLN grid and abandon the micro-hydro power plant. However, micro hydro power plants are still used for productive uses and backup power, although the PLN grid exists. Therefore, the government, grantors, NGOs and development agencies should couple a micro hydro power plant project with small industrial development based on local resource potential.

6.3.4. Environmental and social impact

A private company learned from past experiences about the challenges of introducing projects to local communities and land clearing. Engineering designs that are technically feasible to implement, in many cases, are not applicable due to social factors such as land permit, water use permits and resistance from the local community. Learning from this experience, the company implemented a strategy whereby a corporate social responsibility program must be carried out starting from the planning phase to reduce the impact of resistance from the community, which will cost more if it is not addressed upfront. Likewise, project planning and engineering design must consider alternatives, aligning with the community's social conditions, for example, in determining the appropriate route of the waterway and the location of the weir (Saing, 2021).

Natural disasters such as floods and landslides often make micro-hydro power plants managed by the village community stop operating. Disaster events that do not create major damage to the power plant facilities can still be revitalized by the community as long as it only requires a small maintenance cost. For example, in PLTMH Cihekeu, the community spent about 10 million rupiah repairing minor damage to the penstock due to landslides (Purnama, 2021).

6.3.5. Industrial development

During the reintroduction of micro hydro power technology in Indonesia in the 1990s, local industries such as turbine manufacturers, civil contractors and consultants have been established. PT Heksa Prakarsa Teknik produces Cross-flow turbine T14, Cross-flow turbine T14, Pelton Turbine Heksahydro and Peltric P-14 Turbine. CV. Cihanjuang Inti Teknik produces Cross-flow turbine T14 and Open Flume turbine. PT. Kramatraya Sejahtera produces the Cross-flow turbine T14, Cross-flow turbine T15 and the Propellor KPT-500.

Along with the increasing production capability of micro-hydro turbines by domestic players, the government created a national standard that regulates technology products and services in the micro-hydro sector. Table 6.2. show the list of Indonesia National Standard (SNI) for hydropower that has been applied since 2016.

Table 6. 2. Indonesia National Standard (SNI) for hydropower

No	Year	SNI
1	2016	Commissioning guide for micro-hydro power plants below 100 kW
2	2017	Guidelines for the feasibility study of micro-hydro power plants
3	2018	Propeller turbine's technical specification for micro-hydro power plants
4	2018	Francis turbine's technical specification for micro-hydro power plants
5	2018	The acceptance test procedure for turbine fabrication for micro-hydro power plants
6	2018	Penstock design guide for micro-hydro power plants class D (600 kW – 1 MW)
7	2018	Pico-hydro power plant technical specifications
8	2018	Spesifikasi teknis turbin pelton for for micro-hydro power plants
9	2019	Classification of hydroelectric power plants
10	2019	Specification of crossflow turbine for micro-hydro power plants class A

Local content

The government guarantees the sustainability of domestic industries and supports the increasing use of domestic products by implementing regulations related to local content stipulated in the Ministry of Industry Regulation 54/M-IND/PER/3/2012. For example, the local content requirement for small hydropower projects with an installed capacity of up to 15 MW is stipulated as many as 64.20% of domestic products, 86.06% for local services, and 70.76% for local goods and services combined.

According to Raharjo (2021), the mechanical-electrical component contributes 30% and the civil works component 70% of the total component in a small-hydropower system. The mechanical and electrical component consists of 50% turbine, 25% generator and 25% electrical panel. Most micro-hydropower projects in Indonesia use domestic products and services because local turbine manufacturers can supply the technology domestically. In addition, many civil contractors in Indonesia can build small-hydropower since it does not require advanced technology. Instead of considering local content in domestic projects, local turbine manufacturers also aware of the local content regulations in the destination country for export.

Local industry has been very good at the manufacture of cross-flow turbines. However, this type of turbine has capacity limits, where a capacity between 700 kW to 1 M is more suitable to use Turbine Francis. Therefore, the local industry targets the development of a Francis turbine that is suitable for low head and has a capacity more significant than the cross-flow turbine. In terms of developing larger-sized turbines, local turbine manufacturers feel they do not have the capacity because of limited production infrastructure. In addition, there is an increasing number of competitors from abroad, such as China, India and eastern Europe, such as Slovakia and Slovenia (Raharjo, 2021).

6.3.6. Energy potential

Gross theoretical hydropower potential in Indonesia is 75 GW, referring to a study issued by PLN and Nippon Koei in 1983. This potential is spread across 1249 locations. In 2011 a follow-up study was reported in the Hydropower Development Plan, which was screened at the location and became 89 locations with a total potential of 12.8 GW. The results of this study become inputs in the PLN's power plant development plan until 2027 (P3TKEBTKE, 2021).

From 2020 to 2021, the Center for Research and Development of Electricity Technology, New Energy, Renewable Energy, and Energy Conservation (P3TKEBTKE) collaborated with the Directorate of Water Resources Engineering (PUSAIR) conducted further studies to map updated hydro energy potential data throughout the main islands in Indonesia. The program's objective is to deliver a map of hydropower potential, including large-hydro, mini-hydro, and micro-hydro. This potential study considered utilizing the latest data of water flow, head and deployed GIS technology. This project improved several methodologies used in the previous study. First, this study used WFLOW modelling to calculate dependable flow based on rainfall-runoff data. Second, Digital Elevation Modeling (DEM) 30 meters was utilized to improve head and river elevation data. Third, based on Indonesia National Standard (SNI) 6738:2015, a dependable flow with a probability of 90% (Q90) is used. (P3TKEBTKE, 2021).

The potential study shows that Indonesia has hydropower potential with a Run-Off River scheme of 94.627 MW spread in 52.566 locations. It will be published as a map that can be publicly accessed after P3TKEBTKE acquires intellectual property rights (HKI) (P3TKEBTKE, 2021).

6.3.7. Business models

Niche actors conducted experiments in technology and explored which business models significantly affect small hydro diffusion to a larger market. Initially, there was only the incumbent business model applied in the small hydropower sector. With the low electrification ratio in the 1990s, PLN could not provide electricity access alone. Particularly in remote locations that were expensive to be reached by the grid. Therefore, other business models were needed to support the rural electrification program. The cooperative business model became an appropriate alternative. As the government opened the opportunity for the private sector to participate in power generation, the PPA business model was applied. Detail investigation of the business model will be presented in Chapter 7 as it is part of the sub-research question.

6.3.8. Conclusions

International donors and development agencies have facilitated learning related to technology through a capacity-building approach rather than only a technology transfer approach. With the increasing production of local micro hydro power turbines and projects, the government created a national standard for products and services in the micro-hydro sector. In addition, the government supports the utilization of domestic products for small hydro power and protect the local market through local content regulation. As the niche grows, the network formation became complete, consisting of many government organizations. They create regulations, licenses, and permits that need to be fulfilled by small hydro power developers. In addition, the government also improved the energy potential map of small hydro power in Indonesia.

Niche actors learnt social aspects that cause failures of the previous rural electrification projects and led to the implementation of the cooperative business model, emphasising the active participation of the local community and capacity building that will increase the sustainability of micro hydro power operation. From off-grid rural electrification, small hydro power has been transformed into the on-grid power plant to feed the PLN grid. This shift has created new business models involving private sectors through the private IPP and public-private partnership business models.

6.4. Shielding

6.4.1. Active shielding

Micro-hydro projects introduced by international donor and development agencies in collaboration with local niche actors such as NGOs and the government in the 1990s was a demonstration of active shielding where the donors (i.e. international donor and government) provide grants for micro-hydropower experiments. Moreover, since many international donors participated actively in rural electrification programs in developing countries, the active shielding was not limited to bilateral donor agencies but also involved multi-lateral donor agencies.

Currently, the government is carrying out active shielding through regulations that support renewable energy development, for example, by providing special allocation fund for rural electrification that is regulated in MEMR Regulation No 3 of 2014. In addition, the government also provides subsidies for IPP projects that use public and private partnership scheme. Furthermore, the implementation of the feed-in tariff, philosophically is an example of active shielding from the government, aims to guarantee the IPPs' revenue due to PLN domination in the existing electricity market.

Currently, as stated in the Presidential Regulation No. 10 of 2021 (implementing regulation for Omnibus Law), the government provides active shielding such as tax allowance, tax holiday and granting facility import duty for investment in the prioritized sectors, including small hydropower. However, given that the recent law and regulation are still being criticized by stakeholders and disseminating information regarding this regulation still in the early phase, many small-hydro developers are still questioning the further implementation (Interviewee 3, 2021).

6.4.2. Passive shielding

Passive shielding was also applied since micro-hydropower projects were dedicated to rural areas without access to electricity. In the early development phase of micro-hydropower, when the Indonesia electrification ratio was still around 50%, the implementation of micro-hydropower plants in remote areas was an example of effective passive shielding. At that moment, PLN was not able to provide electricity for all Indonesian people because electricity infrastructures were still limited. Moreover, the extension of the transmission and distribution network to remote areas would be costly given that the supporting infrastructure such as access roads and bridges were not developed yet.

Along with Indonesia economic growth, electricity infrastructure has also been developed massively. As a result, the provision of electricity has been improved significantly, and National Energy Policy (KEN) targets a 100% electrification ratio by 2020. Although recent data indicated that at least 2500 villages still have no access to electricity (Yudha et al., 2021), the PLN grid has reached remote areas, including locations where micro-hydropower plants operated (Anugrah, 2021; Interviewee 1, 2021; Purnama, 2021). The government's mandate to PLN to achieve the electrification target is apparently not in line with passive shielding that needs to be carried out to protect the niche. In some cases, when the electricity from PLN was available, the villagers start to switch their electricity to PLN and abandon micro-hydropower (Anugrah, 2021; Interviewee 1, 2021) or micro-hydropower become an alternative when the PLN grid is disrupted (Purnama, 2021). Micro-hydropower is less attractive than PLN because villagers can get electricity at a low price with subsidies. In addition, they feel more comfortable because they do not need to operate and maintain micro-hydropower plant (Anugrah, 2021; Interviewee 1, 2021; Purnama, 2021).

6.5. Empowerment

Under the current monopolistic electricity sector in Indonesia, it is unlikely that niche actors are able to implement stretch and transform empowerment. It is difficult for niche actors to change regime dimensions such as formal institutions and electricity industrial structures in Indonesia. Any attempt to liberalize the electricity sector is considered opposing the Indonesia Constitution 1945. The government intervenes the electricity market through which tariff is regulated and subsidized. The government also controls the privatization in the power generation sector through regulations in feed-in tariff. In addition, the lock-in mechanism in the coal sector is reinforced through 35 GW power plant projects dominated by coal-fired power plants and supported by coal subsidies policy.

Niche actors use fit and conform strategy to enable small hydro power to compete in Indonesia's electricity sector. Through power purchase agreements with PLN, niche actors attempt to increase the adoption of small hydro power within the existing dominant infrastructure (i.e. coal-based power plant and transmission grid) and the incumbent electricity business model.

6.6. Barriers and opportunities

Barriers are categorized into regulation, financial, policy, social and technology. The analysis is based on interviews and secondary data.

6.6.1. Regulation barriers

Regulations related to small hydropower in Indonesia have undergone many uncertain changes. The developer experienced different treatment before and after 2017. Before 2017, the business model for

IPP applied BOO in which the developer's power plant facilities become the developer's property at the PPA contract. In 2017, based on input from stakeholders who support the nationalization of electricity assets, the government, through MEMR regulation no 12 of 2017, stipulated that small hydropower shall be implemented using the BOOT scheme. The power plant assets will be transferred from IPP to PLN at the end of the PPA period in the BOOT scheme. It is problematic for IPPs because the power plant assets cannot be used as collateral in project financing (Setyowati, 2020). In the same year, this regulation was amended by MEMR regulation no 43 of 2017, which has a positive implication for hydro power sector through the specific changes on article 7 regarding the tariff setting that was previously set at 85% of the highest local BPP to 100% of local BPP. The subsequent changes occurred in the same year, MEMR regulation no 12 of 2017 was revoked by MEMR regulation no 50 of 2017. Thus, the same regulation experienced changes three times in a year.

In 2020, the MEMR regulation no 50 of 2017 was again amended by the MEMR regulation no 4 of 2020. One of the amended clauses is about the changing of the business scheme from BOOT back to BOO. The amendment was made due to pressure from business actors who perceived that the BOOT scheme was detrimental to the investment climate, especially when coupled with unattractive FiT (Adistira, 2021).

The BOO business scheme is preferable for the IPP because they owned the asset at the end of the contract, which may also be extended if PLN still needs the power plant (Adistira, 2021; Suryanto; 2021). Although the BOO scheme has been stipulated in the new regulation, IPPs are now "wait and see", learning from the experience of uncertain regulations (Interviewee 3, 2021). Informants from private firms view the uncertain regulations as a crucial barrier for developing this renewable energy because it negatively impacts investors' interest in investing their shares in such projects.

PPA signed before 2017 have no "take or pay" provision for IPPs, meaning no guarantee PLN will absorb all the electricity production. There will be a take-off risk when electricity demand from PLN is lower than the production capacity of the IPP power plant. Lower demand can be the case in the COVID19 pandemic, where electricity consumption from industries and office buildings might drop. Furthermore, over-supply condition may also be the case due to improper interconnection study in the pre-project phase. It can happen because of inappropriate data input from PLN in the interconnection study, or the IPP projection regarding demand was too optimistic (Adistira, 2021; Suryanto, 2021).

While the 'take or pay' scheme is not applied to private companies, the PPA between PLN and the coal-fired power plant IPP uses a 'take or pay' scheme. It is considered unfair according to small hydropower IPPs because it is more profitable for fossil fuel generation and does not encourage the development of renewable energy (Raharjo, 2021).

The regulated tariff by the government raises the dilemma. On the one hand, IPPs want to have higher tariff since they are profit-oriented companies. On the other hand, PLN, as a state-owned electricity company, has a public service obligation role to the customers with regulated tariff by the government that can not be passed through to the customer. It means that PLN must bear the risk of tariff difference. Although the government promised to bear the burden of electricity subsidies in the end that will be paid to PLN but based on experience, it did not meet the expectations of PLN in terms of payment timeliness and amount (Interviewee 2, 2021). This business scheme is not sustainable for PLN in the long term, and the subsidies will be a burden for the government.

6.6.2. Financial barrier

Under the current regulation of PLN, it requires that the company who want to participate in mini-hydropower as IPP shall have previous experience in developing a mini-hydropower plant. Thus, it becomes an entry barrier for a small company (Suryanto, 2021). Furthermore, the developers that already acquired the PPA contract need to provide an implementation guarantee of 10% of the total investment (PwC, 2019). Therefore, small companies need to partner with established companies with previous mini-hydro project portfolios and provide implementation guarantees to overcome the financial barriers. In practice, they often establish a consortium firm consists of several firms to gain sufficient capital.

Niche actors mentioned that micro-hydro with capacity under 1 MW is not commercially attractive for investors because of high investment and high risk in technical and social aspects. In addition, the customers are the villagers who have a low ability to pay for the higher tariff. Thus, micro-hydro is commonly perceived as a social project instead of a profitable business for the private sector (Mumpuni, 2021; Wijayanti, 2021). Private firms prefer to develop mini-hydropower because business to business scheme with PLN guarantees a higher revenue than directly selling the electricity to the rural community.

Meanwhile, the local banks reluctant to give financing support for small hydro project due to a lack of understanding about the technology. The bank needs to understand how to evaluate the viability of energy potential based on the assessment report. The data accuracy and document completeness are essential for the Bank to analyze the business feasibility. Given that this subject is beyond the Bank's competencies, some assistance from external consultancies is needed.

6.6.3. Policy barrier

Indonesia has experienced significant population growth and economic growth in recent decades. This economic growth influenced the increasing demand for electricity, which also continues to grow. In the era of President Susilo Bambang Yudhoyono's government in 2007, the government launched a 10 GW power plant project in anticipation of demand. Furthermore, in 2015 under President Joko Widodo, the government targeted a 100% electrification ratio to be achieved by 2020. So the government accelerated the development of power plant infrastructure by launching a 35 GW project.

Although endowed with a considerable amount of renewable energy potential, the 35 GW projects are dominated by coal-fired power plants. With the current 29 GW of coal-fired power plants' total capacity, the 35 GW program aims to achieve the target of an entire coal-fired power plant installed capacity of around 56 GW in 2028. Hence, this development will place Indonesia as the fourth-largest coal-fired power plants developer after China, India and Turkey (Kurniawan et al., 2020).

The ongoing projects and contract commitments for 35 GW are difficult to be annulled because it involves many stakeholders and will be costly to be cancelled out. Therefore, the government’s commitment to complete fossil-based power plants development will still be continued (Interviewee 2, 2021). Of the 35 GW project, many coal-fired power plants are being built in Java that creates oversupply condition, especially in the COVID19 pandemic where demand from offices and the industry sector is low. From the short term economic perspective, it seems to be unnecessary to develop additional power plants from renewable energy when supply is higher than demand (Interviewee 2, 2021). Nevertheless, externalities cost will be higher in the long term, meaning that costs related to coal utilization such as air pollution, ecosystem damage, biodiversity loss, and human health are not included in the current electricity tariff.

In the oversupply condition, PLN tends to prioritize absorbing supply from large coal-fired power plant IPP due to "take or pay" provision and set aside mini-hydropower plants IPP without "take or pay" provision in their PPA (Suryanto, 2021, Raharjo, 2021).

6.6.4. Social barrier

Since micro and mini-hydropower projects are often located in remote areas, the developer might deal with indigenous people. Environment protection and management Law No. 32 of 2009 uses the term customary law community for defining indigenous people (Omposunggu, 2018). Law No 32 of 2009 defines indigenous people as a group of people who have lived in a particular geographic area from generation to generation due to ties to ancestral origins, a strong relationship with the environment, and a value system that determines economic, political, social and legal institutions. Most of the indigenous communities in Indonesia still hold strong traditional values associated with natural resources, including water, that might limit their willingness to adopt mycrohydro technology. This condition is challenging for the developer to introduce micro and mini-hydro projects.

Conflicts with indigenous people arise when it comes to land clearing. The government regulates land ownership status and territorial boundaries through the National Land Agency, but this only applies to urban and rural areas, not in the remote area where indigenous people reside. In the areas where indigenous people live, the status of land ownership is not only regulated by the government, but the indigenous people have their own right to manage the land ownership status and its boundary (Saing, 2021).

After completing the legal permit for land utilization from the government, mini hydropower developers have to deal with indigenous people and their leader to negotiate for compensation. Furthermore, construction projects in that area often become a political commodity for an indigenous community leader who wants to benefit from the project on their land and livelihood. No regulation from the government related to the amount of compensation makes the developer spent more additional upfront costs to resolve social matters (Adistira, 2021; Saing, 2021).

As the government mandates PLN to meet the 100% electrification target, PLN gradually extends electricity grids in rural areas. In some cases, the PLN grid is still unreliable where the electricity only available for limited hours per day and often experience blackout. With the low quality of the grid, micro-hydro power plant often still become the first option for the villagers. However, in some locations, the consumers immediately switch to the PLN grid and abandon the micro-hydro power plant when they think that it is more convenient to purchase electricity from PLN without obligation to operate and maintain the power plant.

The project funded from the government grants faces challenges after handed over to the local community. The government budget generally only covers the initial investment cost, not for the operation and maintenance cost. Because micro-hydro is aimed to alleviate poverty in rural areas, the tariff imposed on the community is quite low. In general, it is only sufficient for minor maintenance costs and meager wages for the operators. In Force Majeure cases such as landslide and flood damaging the facilities that need a lot of money to repair. The local turbine manufacturer usually can still support supplying spare parts free of charge for small spare parts. For the major breakdown, the community needs to report to the provincial government as a grantor. However, the process will often take a long time, more than a year, because the government needs to plan the budget for the next year and follow complicated procurement and tender procedures. Hence, the micro hydropower plant is left inoperative.

6.6.5. Technology and infrastructure barrier

Micro hydropower in Indonesia has been developed through a lot of experimentations and project implementations, resulting in the increasing local turbine manufacturer capability. Currently, they can produce Cross-flow T14 turbines, Cross-flow T15 turbines, Pelton Heksahydro turbines, Open Flume turbines, and Propellor KPT-500 turbines. These turbines have also been exported for overseas micro hydropower projects. On the other hand, the condition is not applied to mini-hydropower where the turbines with a capacity above 1 MW can not be produced locally because local turbine producers have limited infrastructure for the manufacturing process (Raharjo, 2021). In addition, local players facing challenges from global companies engaged in the mechanical and electrical component for small hydropower. Therefore, local turbine manufacturers decided to take a niche market in countries such as Japan, where global manufacturers have existed. However, they perceive micro-hydropower turbines production has low economies of scale compared to larger turbines.

The potential sites of small hydropower are generally located in remote areas, far from the grid, difficult to access, and also far from areas that have a considerable demand. The suitable locations are usually located in the upstream parts of the river that commonly have an extensive head difference. Therefore, the first challenge is the mobilization of the equipment in the construction phase. The need for adequate access roads and the rehabilitation of existing roads are things that the developer must consider before carrying out the project. The costs that arise caused by the preparation of road access or bridge infrastructure need to be taken into account in investment costs. It will affect BPP, where if it is too high, it will become unprofitable. Secondly, developers need to invest a considerable amount of capital to build interconnection infrastructure to the nearest grid available (Adistira, 2021; PwC, 2018). The distance may vary greatly depending on the condition of each location.

6.6.6. Opportunities

Growing awareness regarding climate change issues and utilization of renewable energy at the government level and the parliament is an opportunity for niche actors to influence energy policies and regulations. At the landscape level, it also drives financial institutions and banks to provide green financing that can be used to finance small hydro power plant projects. In addition, recent infrastructure development in some rural areas, such as road access, has facilitated developers to mobilize small hydro power technology to remote locations. Moreover, the PLN grid that has reached more rural area provide low investment cost for developers to construct interconnection points.

Since 2015, the Government of Indonesia launched a village fund program. This fund can be used for infrastructure development and human development in rural areas. Between 2015 and 2019, around USD19.14 billion (Rp 268 trillion) of these funds have been distributed to villages (Arifin et al., 2020). This program can facilitate the implementation of micro hydro power under village-owned enterprises (BUMDes) or cooperatives. Furthermore, green financing from global financial institutions can be used to support small hydro power plant development.

The government still also need to provide electricity for 433 villages in the eastern region of Indonesia that currently have no access to electricity. The government still also need to provide electricity for 433 villages in the eastern region of Indonesia that currently have no access to electricity. Potential studies need to be conducted for these villages to determine the most suitable renewable energy sources available locally in these locations. Based on Table 4.2, the eastern region of Indonesia, including Papua, Maluku and Nusa Tenggara, have small hydro power potential that can be harnessed.

In 2020, the government planned to replace 5200 small-scale diesel power plants spread in 2130 locations in Indonesia with renewable sources (Tasrif, 2021, 35:10). Through this program, the Indonesian government expects to reduce oil import, save government spending and reduce emissions from plant operation. The government considers that replacing these power plants can not be done through the expansion of the grid. Therefore, it becomes a good opportunity for small hydropower plant to replace this power plant if there are small hydropower potential in these locations.

In the future, with the growing adoption of electric vehicles (Evs) in Indonesia as global EV producers will enter the Indonesian market. Consequently, electricity demand will increase, and the regime should increase power generation capacity to meet the demand. At the same time, it is projected that in 2050 coal reserves will decrease, and coal-fired power plants will be phased out. Therefore, since a small hydro power plant is considered more stable in supply than other renewable energy that has a problem with intermittencies, such as solar PV and wind power, small hydro power can play a role as a baseload power plant. Finally, it can contribute more to balancing the supply and demand of electricity in the future.

7. Business models

This research reveals business models that have been implemented and planned to be applied by niche actors. Business models of small hydropower in Indonesia primarily differentiate based on the type of actors (i.e. state-owned electricity enterprise, private sectors, the government, community and development agency), source of funding, value propositions and partnership model. This study shows business models that slightly differ in their value proposition, revenue stream, funding, partnership model, and key activities. Four business models will be presented in this study, including the state-owned electricity company, private firm IPP, public-private partnership and cooperatives.

7.1. State-owned electricity company

The business model canvas of state-owned electricity company is derived from analysis of literature study from the company website, PLN statistical report and interview with a respondent from PLN.

Value proposition

The value proposition of the incumbent electricity company business model is to provide affordable electricity service for residential, households, commercial and industrial sectors with the tariff as regulated by the government and approved by the house of representatives. As a business entity, PLN needs to maintain its revenue and profitability. On the other hand, electricity tariff has to be perceived as affordable equally for Indonesians. Nevertheless, willingness to pay in large cities with higher income might be different with most populations in rural areas. Hence, the value proposition of PLN as a business entity is challenged by the role of PLN to manage public service obligation at the same time.

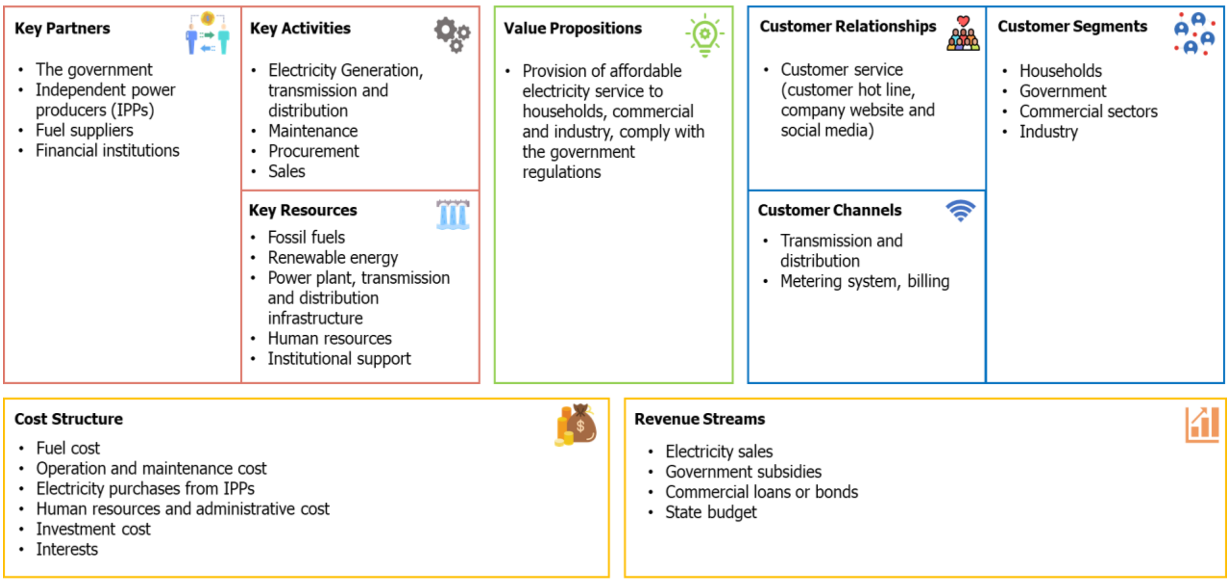

Figure 7. 1. The PLN's business model canvas based on analysis from literature and interview

Key activities

PLN's business activities cover from upstream to downstream in the value chain of electricity production, including power generation, transmission, distribution and sales. Especially for transmission and distribution operation, PLN has a monopoly over the whole asset (PwC, 2018). Currently, around 79% of power generation in the country is controlled by PLN, while 21% is owned by IPPs (Maulidia et al., 2019). Since PLN has been mandated by the law to provide electricity and build electricity infrastructure, managing partnership with IPPs through procurement and PPA is another essential task for PLN. In order to ensure the reliability of electricity supply, PLN has to manage the supply and logistics of fossil fuel (coal, gas and oil) for the power plants spread across the archipelago. While for renewable resources, PLN does not need to be bothered with the supply and logistics of fuel because its energy resources are available locally.

Key resources

PLN's power plant fuel resources are primarily based on fossil fuels (coal and gas). PLN targeted power generated from coal contributes to 54,5% of the overall power plant, gas 22% and renewable 23% in 2025 (PLN, 2019b). PLN has developed renewable energy power plant for decades, for example, large hydropower and geothermal. Since PLN has to sell the electricity at minimum cost and tariff, coal resources that are abundant and cheap are still prioritized by PLN. As an incumbent, PLN supported by regulation and law that sustain monopoly business in the electricity sector. Furthermore, the existing large number of electricity infrastructure asset owned by PLN is the vital resources of PLN. PLN employs around 54.000 workers spread across the country (PLN, 2019b).

Key Partners

As a state-owned electricity company, PLN operates under government policy and regulation. The government regulates low tariffs for low-income households, small businesses, and small industries that PLN must accept and then the government will reimburse the loss as subsidies (Interviewee 2, 2021).

PLN collaborates with EPC companies to develop electricity infrastructures such as power plants, boilers, turbines, generators, electrical substations, transmission, and distribution systems. For developing electricity infrastructure, capital is needed from lenders (i.e. banks and financial institutions).

Instead of its role as an electricity supplier, PLN also plays a role as an electricity off-taker from IPPs. The partnership between PLN and IPPs is arranged in PPA contracts.

Customer segments

PLN is the one and the only customer of IPP. The IPP sells electricity to households, industries, the business sector, the social sector, government offices, and public street lighting. Currently, there are around 79 million PLN customers, categorized into 17 customer groups based on customer types, voltage ratings, and tariffs. Household customers contribute to 91% of the total customer, around 72 million customers (PLN, 2020).

Customer relationship

PLN maintains a direct relationship with the customer. For requesting a new connection, the new customer needs to apply via the PLN website. First, the customer has to read the contract specifying rights and obligations, the scope of works, initial cost, technical requirements, cancellation, force majeure dan dispute. Besides new connection, PLN also provides connection upgrade and temporary connection request.

Channels

PLN has complete control over transmission and distribution infrastructure. As a result, PLN makes a direct transaction to the customers by installing the metering system on the customer side to record the transaction. PLN has branch offices throughout Indonesia, reaching districts in each province. Additional channels are provided, such as website, PLN mobile, social media and call centre to report the customers' problem.

Cost structure

Based on the income statement of PLN 2019, the company's cost structure, from the largest to the smallest, consists of fuel and lubricant cost, power purchase and diesel engines rent, depreciation, human resources, maintenance and other costs. The cost for supplying coal, gas, oil, and lubricant contribute to around 43,1% of the total cost (PLN, 2019b). It means that the company can minimize operation cost by shifting to renewable energy that can be obtained for free.

Revenue stream

PLN get the revenue from selling electricity to the customer (96,54%), connection to new customers (2,43%) and other sources (0,93%) (PLN, 2019b). Since PLN has to sell electricity to low-income households, small business and small industry with a low tariff regulated by the government, the losses must be borne temporarily by PLN. Then, the government will compensate the subsidy and become PLN revenue in the income statement (PLN, 2019b). Although household makes up to 91% of the total number of customers, it contributes only around 41% of the total revenue. On the other hand, industry and business combined with only 5% of the total customer have a higher revenue proportion of around 52%.

7.2. Private company IPP

Encouraged by a renewable energy target of 23%, in 2017, the MEMR approved power purchase agreements (PPAs) between PLN and 50 mini hydro power IPPs. The tariff agreed is ranging from Rp 780/kWh to Rp 1,050/kWh (PwC, 2018). However, financial barriers have hindered 38 IPP projects to receive financial support from banks. The renewable energy target has opened a window of opportunity for private IPPs to invest in mini hydro power plants. The business model described in this study is based on interviews with four respondents from IPP, a literature study and a review of the provisions in the PPA contract. Therefore, it results in a generic business model of private firm IPP in Indonesia.

Value proposition

The value proposition of IPPs' small hydro is primarily to provide clean energy through optimizing local hydropower potential based on commercial principles. Small hydropower is perceived commercially attractive since the resources can be obtained for free with a continuous supply. Therefore, the appropriate feed-in tariff is crucial for private firms to invest in small hydropower.

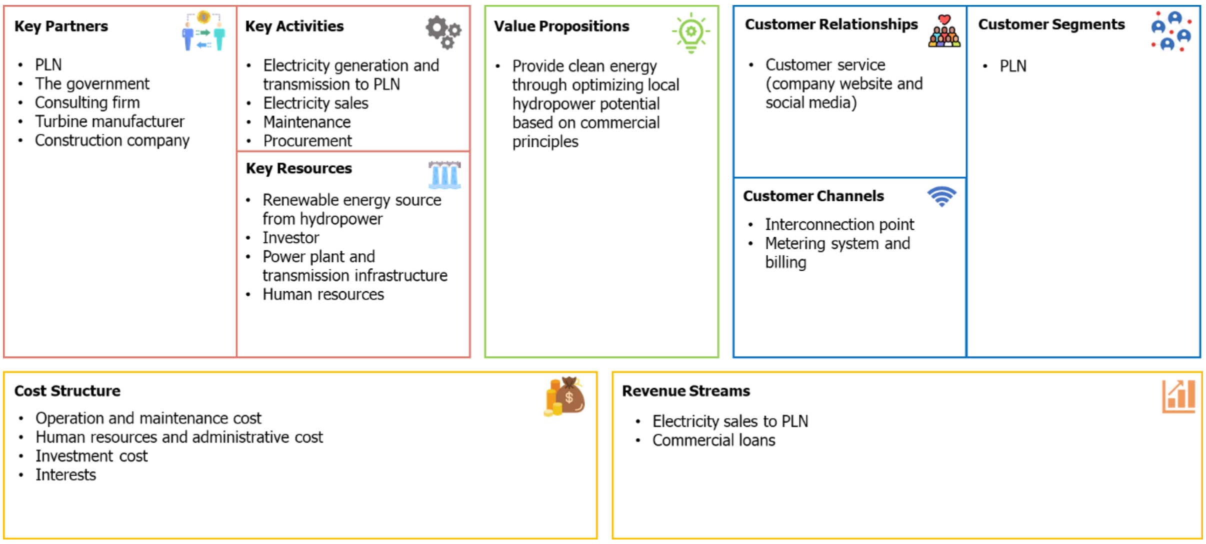

Figure 7. 2. Private IPP's business model canvas based on analysis from literature and interviews

Customer

PLN is the only customer and purchaser of electricity produced by the IPP (OJK, 2014). PLN purchases electricity with provisions set in the power purchase agreement (PPA) such as contract period, rights and obligations of each party, risk allocation, commissioning and commercial operation date, price adjustment, and termination (Adisuryo, 2020). As the purchaser, PLN determines the installed capacity that is needed as planned by PLN.

Key partners

IPP collaborate with PLN in all stages of mini-hydropower development, from project proposal that has to be evaluated by PLN, PPA arrangement until the operation phase. In addition, relationship with the national and local governments is also carried out throughout the project related to regulations, permit and license approval.

Mini-hydro project company can raise capital from lenders consist of banks and financial institutions. However, lenders usually can only provide some part of the project capital. Therefore, the additional equity needs to be acquired through project sponsors, including strategic partners with established small hydro companies and local investors (OJK, 2014).

In the project's initial phase, the company often hires a consultant and an engineering company also is hired by mini-hydro IPP to prepare a detailed engineering design (DED) (OJK, 2014; Suryanto, 2021). The DED is used as a reference for civil works then is executed by EPC contractors. Mini-hydropower plants require turbines with a larger size than micro-hydro that are not yet available locally (Raharjo, 2021; Wijayanti, 2021). Thus, mini-hydro IPPs collaborate with the global mechanical-electrical supplier to provide turbine and generator.

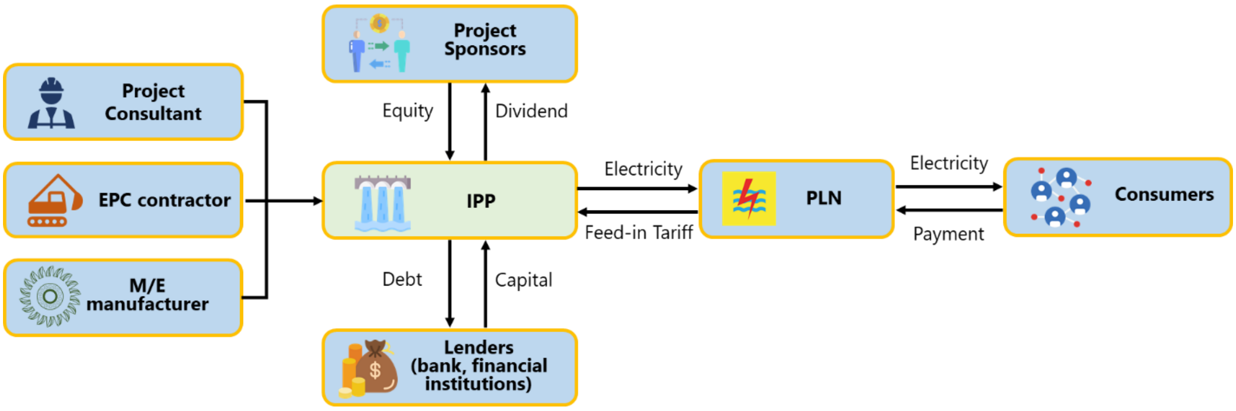

Figure 7. 3. Business model private IPP based on principal investigator analysis

Key resources

Key resources of the IPP are related to financial resources from lenders, project sponsors and company partners, the employee's project management skill, and strong relationship with stakeholders, including PLN, the government, and the local community.

Key activities

The key activities in the initial phase were finding financial resources from project sponsors, lenders and often partnering with other companies to create a consortium. In the development phase, IPP implements project management during power plant construction and collaborates with project consultant, EPC company and technology supplier. After the commercial operation date, IPP focuses on the operation and maintenance of the power plant.

Customer Relationship

The relationship with PLN as the customer is formally stipulated in the PPA contract. Each party has rights and obligations to be fulfilled during the partnership. However, given that many stakeholders involved in a mini-hydro project, such as the local community and government, IPPs have different approaches during the implementation.

In order to minimize social impact, mini-hydro IPP maintains a relationship with local people before the project, during the project and in the operation phase. Before the project, IPP needs to contact and approach the village government leader (administrative) and community leaders. In some instances where the project location is in the hinterland, IPP needs to make a relationship with the tribal chief. In addition, IPPs often have to resolve conflict with local community raise during the project, particularly if the project interferes with their livelihoods. Therefore, the study on environmental and social impacts and CSR programs should be appropriately done by IPP (Saing, 2021).

Channels

The interconnection infrastructure to supply the electricity into the PLN grid has to be built by IPP. Hence, several points need to be considered regarding interconnection to PLN, such as interconnection requirement, agreement on the interconnection facility that IPP and PLN must provide, studies related to interconnection point, transaction point and metering (OJK, 2014).

Cost structure

The costs related to this business model include operation cost, maintenance cost, human resources, administration and overhead cost.

Revenue stream

The IPPs get the revenue from the feed-in tariff paid by PLN. The Feed-in tariff (FiT) was implemented in Indonesia in 2009 for small hydropower plants, which later was implemented for other renewable power plants (Maulidia et al., 2019). With the large Indonesia area, the economic variables differ from one region to another. Thus, the rate of FiT is stipulated differently in different regions. Additionally, the power plant installed capacity also determines the different FiT rates.

The "take or pay" provision is commonly applied for the PPA, which means that PLN guarantees the IPP's revenue through paying minimum IPP's electricity production. However, "take or pay" is not applied for small hydropower, so there will be a risk that PLN does not fully absorb electricity production from IPP (PwC, 2018).

7.3. Public-private partnership

The idea behind the public-private partnership (PPP) business model is to overcome the financial barrier of the government in providing electricity to rural area (UNESCAP, 2013). The term "public" refers to any public-sector entities, such as central government, provincial government, local-owned enterprises (BUMD), village-owned companies (BUMDes), municipalities and government at the village level. According to UNESCAP (2013), the PPP business model has various definitions. However, in the narrowest term, it can be defined as the partnership between public and private sectors with varying levels of roles and responsibilities, risk-sharing, and financial reward is shared based on the contractual agreement. In the broader term, UNESCAP (2013; 40) defines a PPP as *"any type of project that involves a Government as well as private companies, bank, multilateral development bank, or nonprofit organization (including NGO) at any level of involvement"*.

The PPP can have business model variation, including service contract, lease contract, management contract, concession and BOT (UNESCAP, 2013). In addition, another PPP variant has been successfully implemented for rural electrification in Indonesia, namely Pro-poor public, private partnership (5PS), using the prominent example of PLTMH Cinta Mekar in West Java (Guerreiro & Botetzagias, 2017; Purwanto, 2017; UNESCAP, 2013). However, unlike the previous studies on PLTMH Cinta Mekar, this thesis will describe P5S using the business model canvas framework that might be useful for new entry small hydro developer to develop their own business model.

Value Proposition

PPP business models have a different objective that can be profit-oriented, non-commercial, and a combination between profit and social-driven (UNESCAP, 2013). P5S business model is the latter that driven by social objectives while aiming to gain profit. P5S aims to provide clean and modern energy access to rural areas, empower the local community, alleviate poverty and reduce carbon footprint (Guerreiro & Botetzagias, 2017; UNESCAP, 2013).

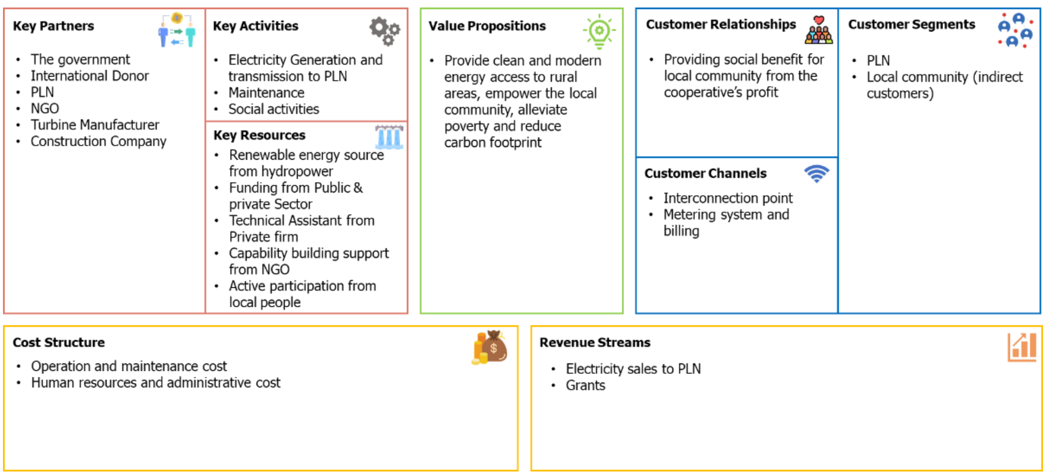

Figure 7. 4. Public-private partnership business model canvas based on analysis from interviews

Key resources

PLTMH Cinta Mekar is a 120 kW micro-hydropower that has been operated since 2004 and is a project collaboration between three parties: UNESCAP as a multilateral donor agency, a private company (PT HIBS) and IBEKA as a non-governmental organization (Guerreiro & Botetzagias, 2017; IESR; 2014). Three parties funded the project with an equal contribution of $ 75,000 from each party. Besides funding, PT HIBS contributed to building the power plant and technical assistance, while IBEKA prepared the social aspects and built the local community's capability.

Mumpuni (2021) argues that technology only contributes to 30% of the success of the transition. Social aspects should also be considered from the beginning of technical project implementation. It is imperative in the rural micro-hydropower project to involve the local community in the construction phase. Through the active participation of the people, social acceptance will be established gradually from the initial phase of the project construction. This model has been proven to improve the project's sustainability in a rural area better than projects that underestimate social conditions and local people's perceptions.

Key partners

After two years of the completion of the construction project, the power plant is operated in a joint venture between a private company, PT Hidropiranti Inti Bakti Swadaya (PT HIBS), and the local community (Cinta Mekar Cooperative) with equal ownership. Besides, the stakeholders involved in the implementation and operation phase consists of IBEKA as the orchestrator of the project implementation, UNESCAP providing the grant, PLN as the customer who purchases the electricity and the governments (i.e. MEMR, MCSME and the Netherland government) that endorse the project (IESR, 2014).

Key Activities

The key activities of this business model are related to the operation, maintenance, and selling the electricity to PLN. In addition, the cooperative also managing the profit to be distributed to the community.

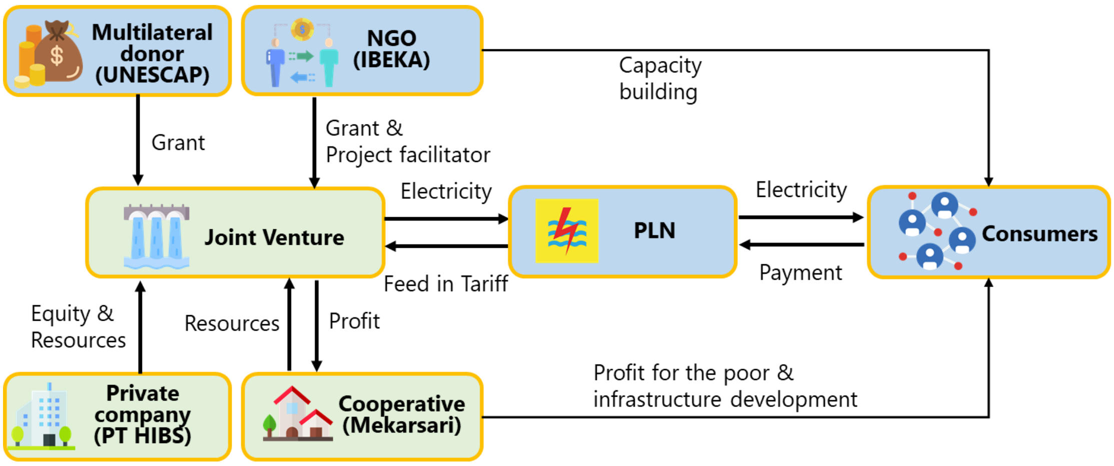

Figure 7. 5. Business model Pro-Poor Public -Private Partnership based on analysis from literature

Customer

PLTMH Cinta Mekar sells the electricity to PLN with the Feed-in Tarif mechanism. The electricity is supply to the PLN grid under a power purchase agreement (PPA).

Channel

In order to supply the electricity for PLN, the interconnection infrastructure was provided by PLTMH Cinta Mekar.

Relationship

As a hybrid between commercial and social business model, the joint venture focuses on generating profit for PT HIBS while the cooperative has a social responsibility to the community. The profit gain by the cooperative was used to provide free connection installation to 122 poor households, gave scholarship to 156 children, built a health clinic, telephone for the community, radio station and other village infrastructure development (IESR, 2014).

Cost structure

The cost incurred from the operation consists of the maintenance cost, human resources and overhead cost.

Revenue stream

PLTMH Cinta Mekar gets the revenue from electricity sold to PLN with total monthly revenue of approximately 25 million rupiahs, and the total net profit after depreciation and maintenance cost is 10 million rupiahs per month. The profit is shared equally between cooperative and PT HIBS.

7.4. Cooperative

The International Cooperative Alliance (ICA) defines a cooperative as *"an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise."* (ICA, 2021). Additionally, according to the Indonesian cooperative law no 25 of 1992, a cooperative is characterized as a business entity that consists of persons doing business activities based on the collective endeavor and cooperative principles to improve the welfare of its members and the community in general. Furthermore, based on this law, cooperative principles entail voluntary membership, management conducted democratically by its members, and distribution of the profit based on the proportion of the share and the contribution of each member. Therefore, the cooperative as people's economic movement based on kinship principle is expected to drive Indonesia's economic growth (Riswan et al., 2017). In 1998, Indonesia already had 58,000 various kind of cooperatives from which rural cooperatives could also involved in power generation sector (Meier, 2001). Ministry of Cooperative promoted rural community participation in electricity sector through cooperative to enchance the benefit of rural electrification for the local community.

This thesis present a cooperative business model with case study of PLTMH Rimba Lestari. The cooperative business model described in this thesis is based on an interview with the manager of PLTMH Rimba Lestari.

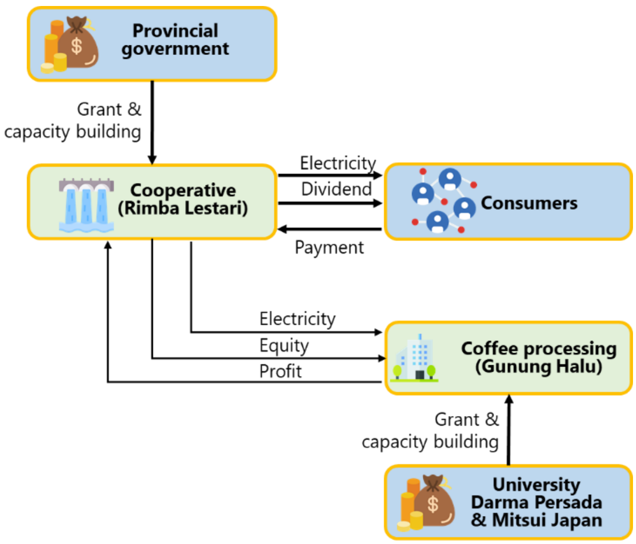

Figure 7. 6. Business model cooperative Rimba Lestari based on analysis from interview

Value Proposition

Initially, the community operated the power plant, and until 2012, they decided to transform it into a cooperative business model in order to get legal status for the business (Sutanto, 2021). The cooperative aims to provide electricity for the local community by harnessing local hydropower potential to improve the community's welfare through the active participation of cooperative members and the local community.

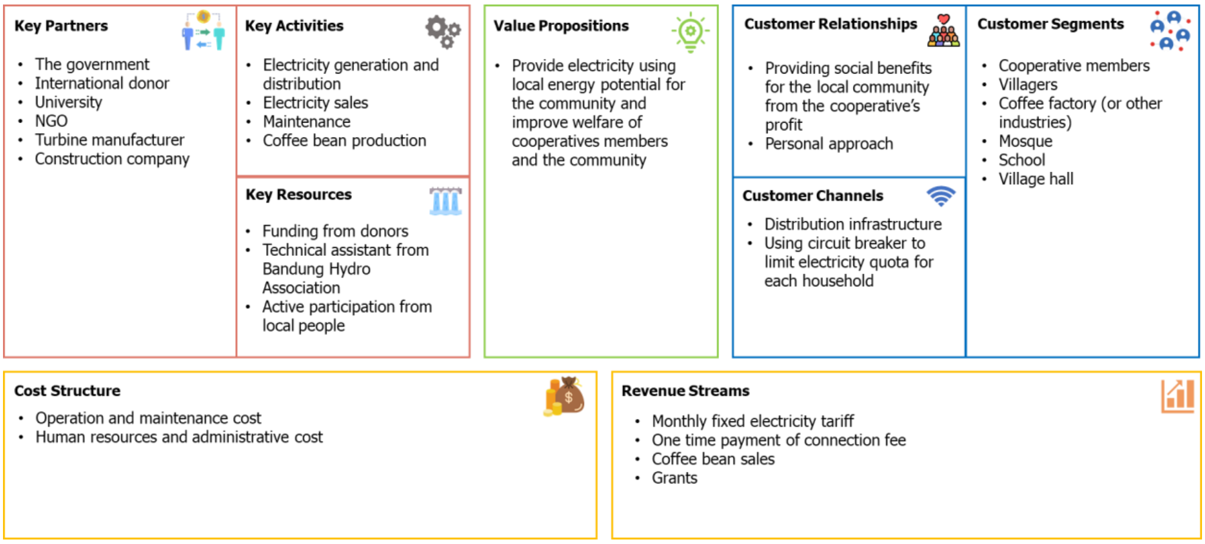

Figure 7. 7. Cooperative Rimba Lestari business model canvas based on analysis from interview

Key resources

The micro hydropower plant was built in 2007 with a capacity of 18 kW through the West Java Provincial Government grant. Since its operation, the MHP has only been used for household needs and public facilities in Gunung Halu Village. However, there was still excess capacity from the power plant that can be utilized. In 2017, In collaboration with the University of Darma Persada, Mitsui Japan provided a grant for establishing a coffee factory. Therefore, the remaining power capacity could be used for productive purposes, such as supplying electricity for a coffee factory.

Not long after the operation of the power plant, the PLN grid finally reached Gunung Halu Village. However, at that time, not all residents became customers of the electricity offered by PLN. Of the 60 households, only 15 households became subscribers of PLN. The rest decided to continue using the electricity from micro hydropower because the voltage offered by micro-hydropower was more stable and reliable at 220 Volts. On the other hand, the electricity supplied by PLN was not reliable, only around 190 Volts during the day and 170 Volts at night. The key resources of micro-hydropower that has put it as the first option than PLN are the reliable hydropower source and a distribution network close to the demand that minimizes losses.

Since the project was funded using the government grant, the power plant operation will be handed offer to the local community. Therefore, the government needs to improve the capacity of local communities to operate and maintain the power plant independently. Thus, various training related to operation and maintenance were given to local people. Additionally, another essentials key resource is the active participation from the local community during the construction process and operational phase. In the construction phase, the local community voluntarily involved in civil works, such as mobilizing materials, preparing power channels, and building the powerhouse.

Key partners

In the beginning, the key partner of the micro-hydro Rimba Lestari was The Agency of Energy and Mineral Resources of West Java Province that provided the grant. Asosiasi Hidro Bandung involved in providing technical assistant related to the potential study and engineering design. Additionally, mechanical and electrical components were supplied from a local turbine manufacturer, CV Cihanjuang Inti Teknik in Bandung West Java. In order to utilize electricity for productive use, in 2017, Rimba Lestari Cooperative collaborated with the University of Darma Persada and Mitsui & Co, Japan established a coffee factory.

Key Activities

The main activity of the Rimba Lestari cooperative was the operation, maintenance, electricity billing to the villagers. However, since the cooperative received the coffee factory grant, the business activities expanded to coffee production. The new line of business has given additional benefits for the cooperative. The excess capacity of the power plant is distributed for productive use, open new job opportunities, and earn extra income from the coffee business.

Customer

According to Sutanto (2021), the cooperative initially operated micro-hydro to provide electricity for around 60 households. The revenue stream comes from the fixed tariff payment from 50 households. Additionally, the cooperative provides free electricity for ten consumers that are categorized as the poor households within the community at a maximum of 225 Watt per household.

Apart from household consumers, Rimba Lestari cooperatives also distribute their electricity to the Gunung Halu coffee factory. In addition, the cooperative also provides free electricity for public facilities such as the mosque, school, and village hall. It is part of the social benefit considering that the local community jointly owns power plant assets.

Channel

Since the PLN grid had not yet reached the village before the micro hydropower plant project, thus the development of distribution infrastructure was included in the grant package. However, due to a limited budget, unlike the PLN distribution channel that uses a metering system, the electricity is supplied to each household at a fixed voltage rating of 450 VA using Miniature Circuit Breaker (MCB). The payment process is carried out manually by visiting every household monthly.

Relationship

The relationship between cooperative Rimba Lestari and consumers is based on the kinship principle. Every issue related to electricity will be solved by personal approaches or discussed in the village meeting.

Revenue stream

Electricity tariff is determined on a fixed basis for each consumer, which is Rp 30,000 per month. Of which 80% of the revenue is allocated to finance the operation of PLTMH, operator and management salaries. While the rest of the payment, Rp 5000, is a mandatory deposit of the consumer that will be used as capital for the coffee processing business. At the end of the year, profits from the coffee processing business will be distributed to consumers who are also members of the Rimba Lestari cooperative. Another revenue stream comes from the one-time payment of the connection fee.

Cost structure

Cost related to the minor maintenance, for example, coupling and bearing replacement, repairing a broken cable and repairing civil components. The cooperative needs to propose to the provincial government as a grantor for major repairs beyond the available maintenance budget. PLTMH employs six operators who receive a monthly wage of Rp 70,000. However, this amount is very small compared to the provincial minimum wage of West Java, which is Rp 1,810,351 (Humas Jabar, 2021).

7.5. Enablers and barriers to business models

Regime and landscape factors may become enablers or barriers to other business models that emerge outside the PLN business model. Table 7.1. presents eight enablers and seven barriers to IPP, PPP and cooperative business models influenced by the regime and landscape factors. In general, the private company IPP has been enabled by an increased renewable energy target from the government that cannot be achieved alone by PLN. Therefore, the government encourages private investors to participate in small hydro power development through IPP business models. In contrast, the emergence of PPP and cooperative business models was driven by a lack of electricity access in rural areas, the availability of grants from governments and international donors, and technical assistance to increase local communities' capability to run these business models. In addition, Indonesia’s geographical condition and weak infrastructure (i.e. road access, bridge and ports) are challenges for PLN’s grid to reach isolated areas. Nevertheless, this is an opportunity for PPP and cooperative business models to develop decentralized small hydro power plants with limited financial resources. The capability of local turbine manufacturers to produce locally made turbines also support PPP and cooperative business model that uses micro hydro power turbines. While private IPPs uses mini hydro power turbines from global turbine suppliers.

Table 7. 1. Enablers and barriers to small hydro power business models in Indonesia

	Factors	IPP	PPP	Cooperative
Enablers	Increasing renewable energy target	*	*	*
	The need to mobilize private investment	*	*	
	Availability of grants		*	*
	No electricity access in rural areas		*	*
	Geographical challenge		*	*
	Capacity building for local communities		*	*
	Local turbine manufacturers		*	*
	Mini hydro turbine from global suppliers	*		
Barriers	Monopoly in electricity retail sector	*	*	*
	Uncompetitive small hydro power tariff due to coal subsidies policy	*	*	*
	Regulated electricity tariff	*	*	*
	In oversupply conditions, PLN prefers lower cost coal-fired power plants	*		
	Uncertain regulation (frequent changes)	*		
	Financial barriers	*	*	*
	Small economy of scale		*	*

The electricity monopoly by PLN is a regime factor that becomes a significant barrier to the three business models. Under a monopoly regime in the electricity retail sector, other business entities are not allowed to sell electricity directly to the consumers except in conditions where PLN cannot provide electricity in particular areas (Law no. 30 of 2009). Meanwhile, the coal subsidies policy has a direct impact on reducing the BPP of coal-fired power plants. Consequently, it lowers the average national BPP and makes the electricity price from small hydro power uncompetitive. In addition, since the government regulates the electricity tariff, the government will compensate PLN with subsidies if the tariff is determined below BPP. These factors strengthen the incumbent business model and hinder other business models.

Oversupply conditions create a specific barrier for the IPP business model in which PLN will prioritize to uptake cheaper electricity from coal-fired power plants. Another barrier to the IPP business model pertains to uncertain regulation resulted from frequent changes that deteriorate private investors' interest. However, private investors are more interested in the IPP business model than the PPP and cooperative business models because it has a relatively larger economy of scale. In general, three business models are hindered by financial barriers.

7.6. Conclusions

Business models presented in this thesis will help to understand barriers and opportunities for Indonesia's small hydro power niche. The incumbent business model reflects the government's control over the electricity sector in Indonesia. The government of Indonesia set the electricity tariff subsidies for the eligible consumers and compensates price differences by state budget given to PLN. The government intervention on tariff setting makes PLN a hybrid company with a profit orientation while having a public service obligation. In hydro power sector, PLN operates mini hydro power plants to feed the electricity into the grid. Partnership with IPP is performed through a power purchase agreement (PPA) with a regulated feed-in tariff. The IPP business model is used to support the incumbent business model and overcome the financial constraints of the incumbent in increasing power generation capacity. However, a partnership between PLN and IPP is perceived unsustainable in the long run because IPPs want to have a higher feed-in tariff that PLN cannot directly pass through to the consumers since the government regulates the electricity tariff. Private firm IPPs are profit-oriented companies that rely on private investors to finance the business. Hence, they focus on larger power plant capacity (i.e. mini hydro power plants). On the one hand, there are opportunities for private firms to involved in the development of small hydro power through IPP business model. On the other hand, the PLN control over the PPA can also limit the adoption of small hydro power since PLN have a right to decide whether to approve or not approved the proposed PPA.

Table 7. 2. Overview of business models of small hydro power in West Java

Component	Incumbent	IPP	PPP	Cooperatives
Power plant type	On-grid	On-grid	On-grid rural electrification	Off grid rural electrification
Power plant size	>1 MW	>1 MW	<500 kW	<100 kW
Customer	All segment	PLN	PLN	Community and productive uses
Partnership	Government, IPP through PPA	PLN trough PPA	Donors and private firms	Donors
Fincancial sources	Loans, bonds, state-budget	Private equity	Grants and private equity	Grants
Tariff	Subsidies and non subsidies tariff	Feed-in Tariff based on PPA	Feed-in Tariff based on PPA	A low monthly fixed tariff

The cooperative business model has emerged as the implementation of micro hydro power plant projects using grants in rural areas needs the active participation of the local community to improve operation sustainability. It is often accompanied by the creation of small businesses that consume electricity from the micro hydro power plant. However, the micro hydro power cooperative business model is not considered commercially viable since the revenue is generated from a low monthly fixed tariff from poor consumers.

The PPP business model applies a similar concept to the cooperative business model. Together with private firms, the cooperative represents the active participation of the local community with a focus on providing social benefit to the community. The PPP business model has emerged to overcome the financial barrier of insufficient grants. Therefore, it collaborates with a private firm to invest in the project. At the same time, the PPP business model gains technical assistance from private firms in the construction and operation of the micro hydro power plant. Given that the PPP might have a larger capacity than a power plant built by a full grant, the power plant can feed into the PLN grid. The PPP business model can expect a higher profit than the cooperative business model since the feed-in tariff is negotiated with PLN through PPA. However, PLN control over the PPA hindered this business model from growing, as in the private IPP business model.

In sum, actors have used the IPP business model to empower niche through incremental improvement in the sociotechnical regime (fit and conform empowerment) while supporting the regime to achieve renewable energy targets. In addition, the cooperative and the PPP business model has been implemented to overcome social and financial barriers.

8. Discussion

8.1. Inter dynamics between three levels

This research integrates MLP and SNM frameworks representing sustainability transition research and nine building blocks of business model canvas developed by Osterwalder and Pigneur (2010). The MLP plays a role as a backbone of the integrated framework that provides inter dynamic analysis between three levels: the landscape, the regime and the niche. Niche development is described using the SNM framework that fits into the MLP framework at the bottom level. In addition, business models frameworks explain niche development from the perspective of socio-economic.

The low electrification ratio in rural areas in the early 1990s as a landscape factor created tension in the regime and motivated PLN to conduct a rural electrification program. However, PLN carried out the rural electrification program by expanding the existing grid and developing diesel power plants instead of using decentralized small hydro power plants to reach rural areas. On the other hand, the low rural electrification ratio created windows of opportunity for the small hydro power niche to develop in Indonesia supported by international donors and development agencies. The small hydro power was then developed through nurturing processes that consist of network formation, shaping expectation and learning. Networks of actors were created through collaboration between international donors, development agencies, local NGOs, central government and provincial government. Bandung Hydro Association (AHB) was established since there was a growing number of professionals and activists involved in small hydro power development. According to Geels (2002), new innovations co-evolve with their markets, policies and institution. Similarly, small hydro power business models evolved to adapt to the current monopolistic structure of the Indonesian electricity market and social conditions in rural areas.

The Asian Financial Crisis 1998 as the next landscape factor created tension to the regime and stopped PLN rural electrification program due to financial constraints. However, this landscape factor again opens windows of opportunity for the niche to diffuse to a larger market. Successful experiments in the niche level attracted more international actors to support small hydropower development and mobilized Indonesian government funding. As a result, the number of small hydro power experiments significantly grew, as indicated by the increasing number of turbines produced by PT Heksa Prakarsa Teknik. Several types of turbines such as Cross-flow turbine T14, Cross-flow turbine T15, Pelton Turbine Heksahydro and Open Flume turbine were produced as the result of learning, experiments, and innovations by local turbine manufacturers. Besides technological innovation, niche actors also experimented with business models innovation to overcome financial barriers (i.e. the PPP business model) and improve operation sustainability of the projects (i.e. cooperative business model).

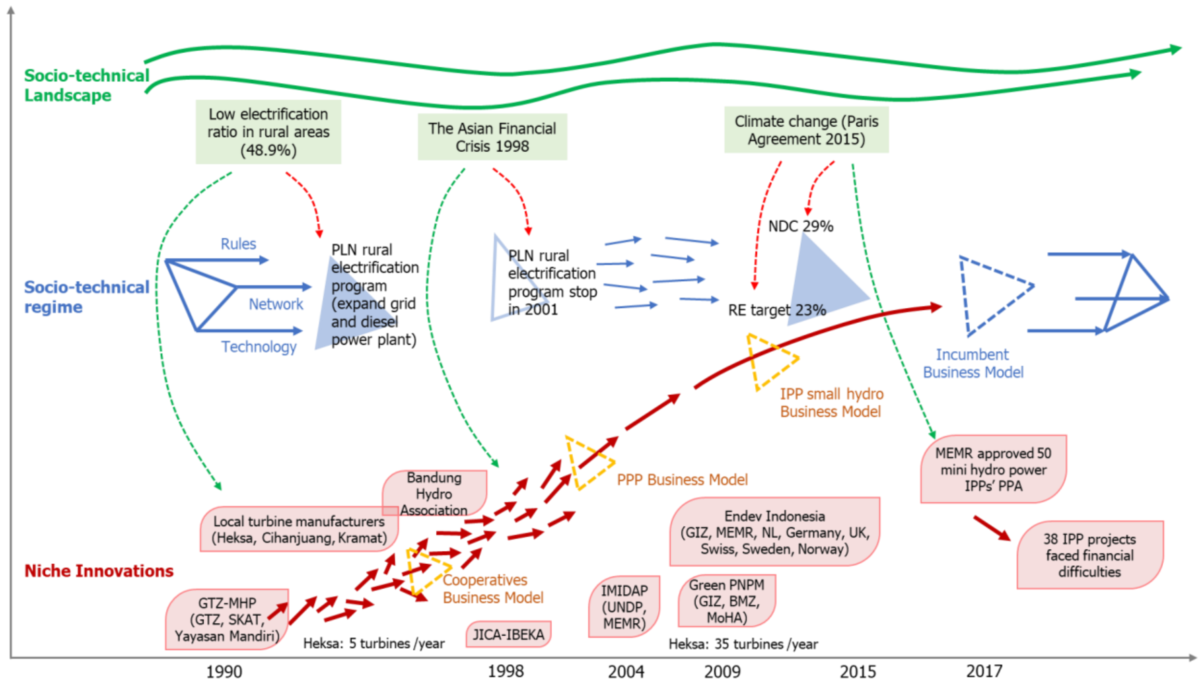

Figure 8. 1. Integrated MLP, SNM and business model framework for the Indonesia small hydro power niche (Adapted from Geels, 2002)

Raising global awareness for climate change mitigation was trickled down to Indonesia. Paris Agreement 2015 was a landscape factor that influenced energy policy formulation in Indonesia. The Government of Indonesia set NDC to reduce GHG emissions by 29% on its effort and 41% through international collaboration by 2030. This target then is aligned with RUEN that set the renewable energy target of 23% in 2025 and 31% in 2050. Additional investment is needed to achieve this target that cannot be borne by PLN alone. Therefore, the government open windows of opportunity for private firms to invest in mini hydro power through the IPP business model. In 2017, although MMER approved 50 power purchase agreements of the private IPPS, 38 IPP projects face financial difficulties.

8.2. The role of business models in the Indonesia small hydro power niche

Adding a business models framework to SNM and MLP to analyze small hydropower niches in Indonesia bring additional insights to this thesis. This thesis presents that the incumbent (PLN) and niche actors have created diverse business models for different purposes. PLN enacts the dominant business model in the electricity sector and uses it to maintain monopoly status with complete control in transmission and distribution infrastructure. This incumbent business model is also reinforced by monopoly policy in the electricity sector, coal sector subsidies, and consumers' subsidies. It has maintained regime stability under the current pressure from landscape development in the climate change issue.

In addition, private firms involved in developing small hydro power through the IPP business model based on a power purchase agreement between a private IPP and PLN. This business model is enacted to support PLN in carrying out the mandate from the Government of Indonesia to achieve the 100% electrification ratio target and renewable energy target. This argument is based on the fact that PLN has limited financial resources to increase the power generation capacity solely and therefore open the opportunity for private IPP companies to be involved in the power generation sector. Meanwhile, a monopoly in the electricity sector is still maintained by PLN by controlling all transmission and distribution infrastructure.

This thesis argues that the private IPP business model is part of the sociotechnical regime implemented to overcome the incumbent's financial barrier by mobilizing investment from private firms to increase power generation capacity, including small hydro power plants. This argument is quite different from Bidmon and Knab (2018), who argue that the business model acts as a dominant industry recipe in the sociotechnical regime and reinforces the regime's dynamic stability. In this regard, regime actors use existing business models of the dominant technology and regime dimensions to exert pressure on niche innovation to grow and create barriers to sociotechnical transition. In contrast, this thesis presents a different insight that in a condition where the regime has a weakness, such as limited financial resources, the regime does not fully exert pressure on niche innovation but instead opens up opportunities for a growing niche.

The public-private partnership business model emerges to overcome the financial barrier and technical barrier in micro-hydropower implementation. Therefore, this business model is funded by grants from donors and equity from the private firm. The private firm also contributes to providing technical competence. In principle, this business model is used a similar model in which the electricity is sold to PLN under a power purchase agreement. The significant difference is in how this business model gets financial resources. Still, an intervention from PLN under power purchase agreement makes this business model also part of a regime tool to overcome its weakness in achieving electrification target without the necessity to extend its transmission grid that requires excessive investment.

Micro hydro power plants in rural areas often use a cooperative business model. It emerged since niche actors (development agencies and NGOs) evaluate that technology implementation in rural areas should be accompanied by local community empowerment. It can be achieved by increasing the capability of the local community and productive electricity use to drive economic activities in rural areas. This business model can be seen more as social entrepreneurship that aims to solve social and environmental issues in rural communities rather than commercial objectives. Therefore, the micro hydro power niche that uses a cooperative business model still needs protection through passive shielding. Passive shielding can be implemented through coordination between government and PLN so competition between micro hydro power plants in rural areas and the PLN grid can be avoided.

Given the high level of regime intervention in the hydropower business model in Indonesia, the role of the business model as an intermediary between niche technology and the sociotechnical regime, as stated by Bidmon and Knab (2018), does not fully occur in the small hydropower sector in Indonesia. Indeed, small hydro power has become part of the electricity regime in Indonesia with increasing installed capacity over time. However, under the current regime policies and regulations that support electricity sector monopoly, this will not sustain in the long run, especially when the electrification target has been achieved and the regime already has sufficient financial capacity.

8.3. Academic contribution

Many articles have been published which analyze sustainable energy transition in developing countries using framework integration between SNM and MLP. Some selected articles are shown in Table 2.1. However, no research has been found integrating business models framework into SNM and MLP. Only recent research suggested the need to add business model components to the SNM framework that inform barriers of niche development (Elmusthapa & Hoppe, 2020). This thesis attempts to integrate the business model framework to the SNM and MLP to gain a rich analysis of niche development, particularly for case studies where many business models of sustainable energy technology are implemented in a specific region or country. In addition, by integrating these frameworks into a historical schematic MLP diagram, this thesis provides rich empirical data on the niche development of small hydro power in Indonesia. This thesis improves the refined SNM framework by Kamp and Vanheule (2015) that only include discussion of business models in one of the learning aspects in the SNM framework. Furthermore, the present study is the first research that integrates a complete business models component analysis with multiple case studies of business models adopted by niche actors and empirical data from niche level and landscape factors that influence niche development. Therefore, this thesis contributes to a more comprehensive integration between sustainability transition framework and business models framework as the academic contribution.

Smith and Raven (2012) suggest further research to apply a more comprehensive SNM framework using additional shielding and empowerment concepts. Therefore, this thesis also contributes to providing a case study of sustainable energy transition in a developing country by reconstructing a small hydro power niche development using a complete SNM framework consisting of shielding, nurturing, and empowerment.

Engelken et al. (2016) argued that the main barrier to implementing new business models for renewable energy in developing countries is weak electricity grid infrastructure. It is understandable because intermittent renewable energy power plants supplying the grid will not add value to the quality of the electricity supply. However, because the small hydro power plant is considered more stable in supply than solar PV and wind power, the small hydro power plant can be a viable option to feed the existing grid. In addition, the geographical challenge faced by the existing grid can be solved by decentralizing power generation such as small hydro power plants. Thus, the Indonesia small hydro power case reveals a new insight that weak grid infrastructure is not a barrier for the new business model to emerge. Instead, it opens a window of opportunity for small hydro power business models that can support the existing grid and can be implemented in rural and isolated areas away from the grid.

The four business models presented in this thesis represent the business models of the actors not only at the niche level but also at the regime level. Thus, it contributes to the literature on sustainable business models where the diversity of business models operated by actors provides insight into the role of business models and the dynamics of interactions between multi-levels. Engelken et al. (2016) showed that literature from developing countries focuses on a single aspect, such as financial, rather than paying attention to other business model components that might also be important. Answering this weakness, Elmustapa and Hoppe (2020) presented additional analysis, including financial and knowledge transfer components in the business models of solar PV in Lebanon. Furthermore, Elmustapa and Hoppe (2020) suggested that future research can be extended beyond these aspects. Therefore, this thesis presents a complete analysis of nine building blocks of the business model developed by Osterwalder and Pigneur (2010) for each presented case to reveal other important aspects that influence small hydro power business model development in Indonesia. As a result, besides financial and transfer knowledge, the customer and relationship element plays an important role in the small hydro power business model in Indonesia, where the relationship between PLN and private firms creates the IPP business model. In addition, low-income customers in rural areas shape the cooperative business model.

Researchers argue that landscape factors that pressure the regime, including demographic shift, macroeconomic condition, financial crises, wars and natural disasters (Geels, 2002; Geels, 2019; Smith et al., 2005). Apart from these landscape factors, the Indonesia case adds another important landscape factor that pertains to the Indonesia geographical challenge. This landscape factor creates pressure on the regime and opens a window of opportunity for the small hydro power niche to develop.

Geels (2019) argued that landscape development exerts pressure on the regime, destabilizes the regime and creates windows of opportunity for the niche to break through to the regime level. However, a different pattern is shown in the Indonesia case. A low rural electrification ratio in the 1990s did not destabilize the fossil fuel regime, but quite the opposite, it encouraged PLN to carry out the rural electrification program by using diesel power plants and expanding the existing grid-based on fossil fuel. At the same time, the low electrification ratio in rural areas in Indonesia create windows of opportunity for niche actors to develop small hydro power in rural areas. From these findings, the landscape factor might open windows of opportunity for niche, but it can also stabilize the regime, depend on the context.

In the last 30 years, the prominent research topics on small hydro power in Indonesia are related to the energy potential study, engineering design, economic feasibility study, operation and business sustainability. In general, the previous works studied small hydro power in Indonesia only at one point in time. No research has been conducted to analyze small hydro power development in Indonesia with 30 years time frame. The only research available that took a longer period between 1990 and 2001 was presented by Meier (2001) to evaluate small hydro power niche development by using multiple case studies of projects since the reintroduction period. Given that many factors from landscape and regime change in the last two decades, it is important to provide a complete historical niche development from the 1990s until now that can be used for learning. Therefore, as another academic contribution, this thesis presents small hydro power niche development in Indonesia within the last three decades that has never been done by any research before. In addition, it contributes to the knowledge gap on SNM studies for the global south countries that may offer different insights.

8.4. Practical contribution

Researchers have focused on micro-hydropower development and put mini-hydro power in the same classification based on installed capacity. This thesis shows that micro-hydropower and mini-hydropower in Indonesia have different business models and diffusion paths, although categorized in the same category of small hydropower. Technologically, the same concept is applied for both niches, and they use the similar component and run-off river principle that distinguishes them from the large hydropower. However, micro and mini hydropower use different business models to overcome barriers of large market diffusion. Therefore, in formulating the energy plan for the national and provincial level, differentiation in policy and regulation should be made between micro hydro power and mini hydro power.

By using the concept of passive and active shielding, it can be observed that some of the government policies and regulations are conflicting and hindering the transition of small hydropower in Indonesia. For instance, passive shielding applied for micro hydro power plants in remote areas was not aligned with the PLN grid expansion plan. As a result, penetration of the grid to the remote area has a detrimental effect on the existing micro-hydro power plant.

8.5. Limitation and further research

Due to limited respondents willing to be interviewed, the business model case study might not fully represent the whole business model. It is also related to the weakness of a single case study in which it has limited generalizability of findings. Therefore, it is recommended for future studies to have more respondents to gain better case study representation. In addition, respondents from BUMD and BUMDes might be helpful to gain more insights on niche development and business models. Since many actors involve from the multiple-level, further research need to be done by using focus group where the information can be validated.

Since the respondents are limited, particularly persons who have experience in small hydro power development since the 1990s, some landscape and regime level factors are analyzed based on desk research. Therefore, it is advisable to have more respondents that have been involved in micro hydro power projects since the reintroduction period to validate historical landscape factors and regime pressures.

Kamp and Vanheule (2015) suggested that expectations can be differentiated based on the origin of the expectations that influence niche development (i.e. exogenous and endogenous expectations) and the expectation of actors in the internal niche and external niche. However, this research cannot directly collect insights from the actors outside the niche, such as banks and financial institutions, due to limited respondents available. Therefore, the analytical framework developed in this thesis does not include external expectations. Still, insights on the negative and positive expectations of actors outside the niche, such as financial institutions, have been informed by niche actors through interviews.

9. Conclusions & recommendations

9.1. Conclusions

Based on the findings discussed in the previous sections, this section concludes by first providing answers to sub-questions and then answering the main research question.

1. **What are the main actors and factors that have influenced small hydro power niche development?**

In the early 1990s, international donors and development agencies were motivated to increase electricity access for rural areas in developing countries, conducted micro hydro power plant experiments in West Java collaborated with local NGOs. International donors and development agencies contributed to transfer technology, provide grants and technical assistance. The successful experiments stimulated positive expectations within the niche and attracted the central and provincial government's attention to micro hydro power development, which led to additional funding. Technological learning increased the capability of local engineers. Some of them went on to establish local turbine manufacturers and local NGOs. The positive expectation and the result of learning attracted new actors, and actor composition increased, covering the entire supply chain. Moreover, heterogeneous actors in West Java that shared a common expectation then established the Bandung Hydro Association (AHB) that has a mission to facilitate quality improvement of the technology through knowledge sharing. At the government level, a group of actors is established related to regulations and permits, including Investment Coordinating Board, Ministry Energy and Mineral Resources, PLN, Ministry of Environment and Forestry and Ministry of Public Works and Public Housing (See also Table 6.1).

Indonesia's geographical condition poses a challenge for the PLN to expand the grid because it needs an excessive investment. Meanwhile, the Indonesian government must develop rural and isolated areas to provide equal economic distribution for all people. This factor creates a positive condition for niche actors to develop micro hydro power plants in rural areas to provide electricity for local communities. In addition, micro hydro power cooperatives were established to empower local communities.

The Asian Financial crisis in 1998 significantly influenced the development of small hydro power in Indonesia. PLN faced a financial problem after the Asian Financial crisis in 1998 and disbanded the rural electrification division in 2001. This condition created a window of opportunity for the small hydropower niche to grow. In 2015, the climate change issue created tension on Indonesia's electricity sector, changing Indonesia's energy policies towards reducing carbon emissions and using renewable energy. The sustainable development issue on the sociotechnical landscape-level also created tension on the regime level to provide affordable and clean energy, as stated in the SDG7 targets. These targets are aligned with the targets in Indonesia's General Plan of National Energy. Motivated by achieving renewable energy target, the government opened windows of opportunity for private IPPs to involve in small hydro power development through power purchase agreement with PLN. However, private companies are only interested in mini hydro power development with more than 1 MW installed capacity because it is more economically feasible than micro hydro power.

2. What are the barriers and opportunities with regard to small hydropower implementation in Indonesia?

Indonesia's small hydro power sector faces several barriers, including regulation, financial, policy, social, and technology. Mini hydro power sector experienced regulation changes three times in 2017 related to business schemes (i.e. BOO and BOOT) and tariff setting. Although the changes are beneficial to private firms and investors, they perceive that frequent regulation changes reflect uncertainty in this sector and lead to "wait and see" strategy. In addition, the "take or pay" provision for coal-fired power plants, meaning that PLN will absorb all electricity produced by coal-fired power plants, is considered unfair for mini hydro power that does not receive the same provision. A regulated tariff is also considered unsustainable for PLN, as it has to bear the subsidies for the long term and also forms a substantial burden to the central government's budget.

Due to its small economy of scale, micro hydro power is not commercially viable for private investors, especially under the monopoly regime and subsidized electricity tariffs. Therefore, micro hydro power is positioned as a social project that relies on donors rather than a profitable business. On the other hand, financial barriers in mini hydro power plants are due to the provision to provide implementation guarantees of 10% of the total project value. At the same time, banks are reluctant to finance mini hydro power plant projects because they are considered risky. In addition, banks do not have capacity to evaluate technical and economic feasibility of small hydro power plants due to lack understanding of the technology.

Another barrier pertains to the 35 GW project of the national government, which is dominated by coal-fired power plants that create an entry barrier for small hydro power plants in electricity oversupply conditions (as experienced in the Java and Bali electricity grids). In terms of social barriers, there are often issues between developers and indigenous communities regarding land clearing, particularly on customary land ("tanah adat"). Although the government regulates customary lands, usually there are overlapping claims over customary lands, hence creating tenurial conflict. Regarding technology barriers, the lack of production infrastructure hampers local turbine manufacturers to produce turbines with the capacity of more than 1 MW. However, currently mini hydro power turbines are supplied from global turbine manufacturers.

Growing awareness regarding climate change issues and utilization of renewable energy at the government level and in the parliament can be seen an opportunity for niche actors to influence energy policies and regulations. At the landscape level, it also drives financial institutions and banks to provide green financing that can be used to finance small hydro power plant projects. The 433 villages in the eastern region of Indonesia that still have no access to electricity can potentially serve as a suitable market segment for small hydro power plants. Furthermore, the small hydro power can be an appropriate choice to replace 5,200 small-scale diesel power plants. In addition, village funds from the central government can be used to establish village-owned enterprises (BUMDes) or cooperatives for developing micro-hydro power in rural areas. Furthermore, recent infrastructure development in some rural areas, such as road access, has facilitated developers to mobilize small hydro power technology to remote locations. Moreover, the PLN grid that has reached more rural areas providing low investment cost for developers to construct interconnection points.

3. **How have current business models influenced small hydro power niche development in Indonesia?**

The paradigm shift of international donors and development agencies at the beginning of the reintroduction period in the 1990s from focusing on pure technology transfer to capacity building of local community influence how micro hydro power business was implemented. International donors and development agencies collaborate with local counterparts both on the technical aspect and business aspect. Local NGOs that focus on empowering rural communities introduce small hydro power technology to drive local economies in rural areas. It was implemented through the cooperative business model in the power generation sector in Indonesia. In the 1990s, the Ministry of Cooperative promoted this new business model among various types of cooperatives established in Indonesia.

In addition, the public-private partnership (PPP) business model in power generation emerged in 2004 to overcome the financial barrier. Grants from donors may not be sufficient to fund the project. Hence this business model improves the cooperative business model that formerly only relied on grants from donors. The PPP business models attempt to mobilize resources from partners to achieve economic and social benefits. In contrast to a firm's profit-oriented business model, the cooperative and PPP business models share the same social goal. Both business models aim to help poor people in rural areas to get access to electricity. Indeed, these business models have proven to increase the adoption of micro hydro power plants. However, both business models have to compete with the existing incumbent business model to contribute to the increasing share of small hydro power in the overall energy mix.

The Asian Financial Crisis in 1998 has a significant impact on the rural electrification program that PLN was carrying out. Hampered by financial constraints to expanding power generation capacity and transmission grid, PLN as a monopolistic company opened an opportunity for private investment to participate in the power generation sector while still retaining full control over the transmission sector. In addition, the renewable energy target of 23% has opened a window of opportunity for private IPPs to invest in mini hydro power plants through PPA that is influenced by regime dimensions (i.e. policy, tariff, market). Niche actors have used the IPP business model to empower niche through incremental improvement in the sociotechnical regime (fit and conform empowerment) while supporting the regime to achieve renewable energy targets.

4. How can small hydro power initiatives be stimulated?

Since the incumbent business model imposes a blocking mechanism for other emerging business models to grow through regulations and policies, utilizing the shielding concept is appropriate to answer this sub-question. Passive shielding should be maintained to avoid competition between the small hydro power niche and the incumbent. It can be done by adjusting regulations to guarantee that the PLN grid will not be expanded to locations where small hydro power has been implemented. Indeed, a high-performance requirement also needs to be set for these small hydro power plants to ensure a reliable electricity supply. The cooperative and PPP business model as a niche can be protected by market segmentation (i.e. rural areas) and quota implementation (i.e. prioritized for villages that have local small hydro power potential). In addition, the village fund provided by the Government of Indonesia can potentially facilitate the creation of village-owned enterprises (BUMDes) in small hydro power plant. As a result, a new business model with collaboration between village-owned enterprises and private firms may emerge.

Subsidies policy for coal-based power plants helps PLN to have a lower BPP, and Domestic Market Regulation (DMO) ensures coal supply for domestic power plants. Thus, these regulations reinforce the coal regime. On the other hand, regulation on price setting based on the highest BPP is unattractive for small hydro power generation since it has to compete with cheaper coal-based power generation. Moreover, coal-based power generation has larger economies of scale because it is currently the dominant design in Indonesia electricity sector, compared with small hydro power that needs considerable investment to increase its adoption. In order to stimulate the small hydro power niche, active shielding should be introduced. The government should also provide subsidies in tariffs and tax breaks for small hydro power. The improved regulations such as the BOO scheme and the “take or pay” that is more attractive for small hydropower investors need to be maintained. It may attract more private investors as long as they perceive uncertainty in the absence of clear regulations.

We can expect innovative business models to emerge if the electricity sector in Indonesia is not anymore operating under a state monopoly regime. The liberalization of the electricity sector in Indonesia, particularly in the power generation sector, may create new business model(s) since the retail consumers can choose from which companies to buy electricity. In addition, they also can play a role as a producer and consumer at the same time. Furthermore, introducing competition in the power generation sector may encourage PLN to seek cheaper renewable energy alternatives such as small hydro power.

5. Answering the main research question, *"How has the small hydro power market niche developed in Indonesia and how did business models facilitate niche development?"*

The development of small hydro power in Indonesia has been influenced by low electrification in rural areas in the 1990s that encouraged international donor and development agencies to provide funding and technical assistance for developing micro hydro power plants. Successful implementation created positive expectations among niche actors and attract the Government of Indonesia to involved in niche development. The Asian Financial crisis in 1998 created pressure on the regime in which the incumbent constrained by a financial issue to continue the rural electrification program. It opened a window of opportunity for private firms to increase their involvement in small hydro power. In addition, to achieve a renewable energy target of 23%, PLN needs to attract private firms to develop small hydro power through a partnership with IPP under the power purchase agreement. The micro hydro power market in Indonesia is supported by local turbine manufacturers' that has been able to produce locally made turbines through a learning process in technology. However, local turbine manufacturers still have limited production facility to produce turbine with more than 1 MW capacity. Therefore, mini hydro power turbines are supplied by global turbine manufacturers.

Due to its small economies of scale, the micro hydro power plant is not commercially viable for private investors. It has been perceived as a social project that relies on donors rather than a profitable business. The cooperative business model has been used to empower rural communities and improve operation sustainability. The financial barrier is the rationale behind the innovation of the public-private partnership business model. Both business models contribute to the adoption of micro hydro power with grant schemes. On the other hand, the mini hydro power plant is more attractive for private firms due to its larger capacity than the micro hydro power plant and having certainty from the consumer side, which is PLN, under the power purchase agreement. The private IPP business model has supported PLN to increase the small hydro power contribution to the total energy mix.

9.2. Recommendations

The concept of niche shielding needs to be used systematically by the Indonesian policymakers to formulate energy policies and regulations to allow the small hydro power niche to grow. Passive shielding can be applied to the remaining 433 villages in the eastern region of Indonesia that still have no access to electricity. The Government of Indonesia should give more opportunities to grow in this particular market segment and protect the niche from grid expansion. In implementing the replacement program of 5,200 diesel power plants with renewable energy power plants, the government should apply a quota policy for small hydro power plants to contribute by considering local energy potential. In addition, developers, the government and PLN should coordinate concerning the future grid expansion plan of PLN to avoid competition between the PLN grid and small hydro power in the future.

Apart from passive shielding, which entails geographical protection, market segmentation and quota, active shielding can be applied to protect the small hydro power niche through regulations, tariffs and fiscal incentives such as tax and import duty. Several measures can be implemented regarding active shielding:

1. The government should implement a “light-handed regulation” for small scale projects to encourage private investment and reduce the risk of investment (Setyowati, 2020). For example, the “light-handed regulation” that has been adopted in the India Electricity Act exempts stand-alone mini-grid from regulatory tariff setting (i.e. tariff decided based on negotiation with the consumer) and exempts from licensing. Another example is that small-scale projects below 100 kW in Tanzania do not require regulatory tariff approval (IRENA, 2016).
2. To make the BPP of small hydro power more competitive compared to coal-based power plants, the Government of Indonesia should reduce subsidies for the coal industry. However, the fossil fuel regime might resist this policy.
3. The "take or pay" provision and the BOO scheme are more attractive for private IPP because PLN guarantees private firms' revenue, and private firms will become the owner of the power plant. Therefore, this regulation should be maintained to attract private investors.
4. Fiscal incentives such as income tax reduction and import duty exemption should be given to small hydro power projects.

To improve the capacity of local turbine manufacturers, the Government of Indonesia should consider facilitating the technology scale-up from micro hydro power turbines to mini hydro power turbines. However, it should be accompanied by domestic market creation and tightening local content regulation for mini hydro power plants.

Monopoly and the government’s control over the electricity sector in Indonesia have hampered innovative business models to emerge. Therefore, liberalization should be introduced gradually in the Indonesian electricity sector. At least, the government should formulate a regulation that allows consumers to choose which source of power plant their electricity is supplied. Along with the growing awareness of climate change and sustainable energy transition, the increasing demand for small hydro power might be expected.

9.3. Societal relevance

Although the electrification ratio in Indonesia currently is around 99%, there are still 5 million that makes up 1% of Indonesian who live without electricity access (Sukmawijaya, 2020). The challenging geographical location is the main obstacle for the government to provide electricity for Indonesians living in remote and isolated areas. Therefore, this research aims to provide insights and recommendations to increase electricity access for rural communities in Indonesia by using small hydro power that can be implemented in many rural areas in Indonesia. Comprehensive analysis on inter dynamic between the landscape, the regime and the niche in this research provides insights on barriers and opportunities that policy makers can use to reformulate energy policy and regulations that support small hydro power development. In addition, this thesis serves as a guide for renewable energy entrepreneurs who are interested in developing small hydro power in Indonesia. Four business models described in this thesis also provide information on how small hydro power business operates that can be used as a reference for policy makers and entrepreneurs to improve the existing business models and develop innovative business models.

9.4. Management of technology relevance

This thesis is aligned with some of the concepts taught in the Management of Technology (MoT) program. First, from the perspective of managing a company, this thesis provides empirical data of small hydro power business models using business model canvas. Different business models of a state-owned electricity company, private IPPs and cooperatives reflect how they operate and commercialize small hydro power technology. This thesis addresses how profit-oriented companies operate (i.e. PLN and private firms) and how social entrepreneurship is developed through the cooperatives business model. Second, from the perspective of innovation, the small hydro power business models emerged incrementally under a state monopoly regime. It seems that monopoly in the electricity sector in Indonesia stifles radical innovation in the small hydro power business model. Third, the monopolistic electricity market influences the competition between fossil-based power plants and small hydro power plants in Indonesia. Therefore, it provides different insights from the electricity market in other countries that have been liberalized. Fourth, it can be seen that geographical proximity influence niche actors to form a geographical technology cluster for small hydro power in West Java and create a collaborative network under Bandung Hydro Association (AHB). Finally, a typical MoT question: “what kind of technology does Indonesia need and when? need to be answered. This thesis suggests that small hydro power is an appropriate clean energy technology to supply the electricity in rural areas and feed into the grid that gains the momentum of climate change and can be more competitive under a liberalized electricity market.

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Appendix A. Interview protocol

Information Sheet – Research Small hydropower in Indonesia

Research Title : Small Hydropower in Indonesia, A Niche Development Analysis
Researcher : Tofan Azhar Hakim
Affiliation : Delft University of Technology
Email : *tofanazharhakim@student.tudelft.nl*

Purpose of Research
Thank you for agreeing to be interviewed as part of the small hydropower research project. This study has two objectives. First, to investigate the development of small hydropower in Indonesia in term of the actors' expectation of small hydropower, actors' learning process (i.e. technical, regulations, economic, cultural and environmental aspects) and how the network of actors involved in small hydropower development. Second, to investigate the role of the business model in facilitating the transition of small hydropower in Indonesia. In the end, this research will provide policy recommendations to facilitate the large-scale diffusion of small hydropower in Indonesia.

Tujuan Penelitian
Terima kasih telah bersedia untuk menjadi narasumber untuk wawancara proyek penelitian small hydropower di Indonesia. Penelitian ini memiliki dua tujuan. Pertama, untuk mengetahui perkembangan small hydropower di Indonesia dari segi ekspektasi aktor, proses pembelajaran (aspek teknis, regulasi, ekonomi, budaya dan lingkungan) dan bagaimana interaksi antar aktor yang terlibat dalam pengembangan small hydropower. Kedua, melakukan analisa peran model bisnis dalam memfasilitasi transisi pembangkit listrik tenaga air kecil di Indonesia. Pada akhirnya, penelitian ini diharapkan dapat memberikan rekomendasi kebijakan untuk memfasilitasi penerapan small hydropower secara lebih luas di Indonesia.

Data collection
The data collection will be conducted through an online video interview, which will be recorded. The interview will take 45 to 60 minutes. Your participation in this study is entirely voluntary, and you have the right to stop the interview or withdraw from the research at any time without having to give an explanation and with no consequences.

Metode pengambilan data
Pengambilan data dilakukan melalui wawancara video online yang akan direkam. Wawancara akan memakan waktu 45 hingga 60 menit. Partisipasi Bapak dalam penelitian ini sepenuhnya bersifat sukarela, dan Bapak berhak menghentikan wawancara atau membatalkan kapan saja tanpa harus memberikan penjelasan dan tanpa konsekuensi.

Data handling
If you would like to be anonymized, your name and organization will be replaced by the term "Interviewee number" and "general job or title". The author will transcribe the interview, use it in the analysis, and present it in the thesis report. The interview recording is only accessible by the author.

Penanganan data
Jika Bapak ingin nama dan organisasi tempat bekerja dirahasiakan, maka dalam laporan thesis akan diganti dengan istilah "Nomor Interviewee" dan "pekerjaan atau jabatan secara umum". Penulis akan menyalin wawancara, menggunakannya dalam analisis, dan mempresentasikannya dalam laporan thesis. Rekaman wawancara hanya dapat diakses oleh penulis.

Interview Questions

Introduction

1. Please tell me about yourself and your experience with small hydropower or your organization?
2. Why did you or your organization decide to involve in small hydropower development?

Shaping expectation

3. What are your expectations regarding small hydropower technology? How widely it will be implemented (e.g. rural electrification, distributed generation, industry or national grid)?
4. Have your expectations changed over time, and why?

Network Formation

5. What kind of organizations do you collaborate with?
6. Who are the main actors, and what are their roles in small hydropower development?
7. Do you see challenges in the collaboration and coordination between actors? How to overcome these challenges?

Learning

8. What have you learnt on small hydropower, and what may others have learnt? (e.g. technical, regulation, laws, finance, organization, users, and environmental sustainability?)
9. How does the community think about small hydropower plant?
10. Do you have any experience regarding the resistance from the local or wider public? If any, how your organization solve the problem?

Landscape development

11. How do factors such as climate change, macroeconomic, Covid-19, and political circumstances may add to barrier or opportunities in regulations, financing, user preferences and technology?

Barriers and opportunities

12. What are the barriers to small hydropower development? (e.g. policy, regulation, laws, socio-cultural, technological, financial, market?)
13. What do you see as the opportunities that can accelerate the future implementation of small hydropower?

Business model (**for business actors**)

14. Could you describe how your business work? (i.e. the customers, how to reach the customer, key partners, main activities, company resources, revenue stream and cost)
15. According to you, what makes your business successful?
16. How do the current regulations and policies support or constrain/limit your business model? Do you think the existing regulations and policies need to be improved?

Business model (**for non-business actors**)

17. Do you think the existing regulations and policies need to be improved to facilitate the current business models of private firms, local state-owned enterprises and cooperatives?

The concluding question

18. What actions should the relevant actors do to accelerate small hydropower implementation to achieve renewable energy target by 2025?
19. Is there any additional information that you would like to add regarding this topic?
20. Are there any recommended contact for further interview?