Master Thesis

Rooftop PV in Indonesia: A Niche Development Analysis

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

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MSC Management of Technology

TU Delft

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Executive Summary

Problem statement

To achieve the sustainability goals of 23% renewable energy by 2025, 29% emission reduction by 2030, and net zero-emission in 2060, Indonesia needs to accelerate the transition to renewable energy such as solar energy. Despite the abundant solar energy potential, the contribution of solar PV has only reached 0.05% of the energy mix in 2021 (MEMR, 2021a). The development of solar PV face challenges such as land availability, land development and acquisition, geographical problem, and timely permits for onshore project (Patil et al., 2017). A niche rooftop PV serves as an alternative to solve these problems. This study focuses on rooftop PV niche development in the sustainability transition of Indonesia.

According to Geels et al. (2017), the sustainability transition is a complex process due to the involvement of various stakeholders, including policy-makers, companies, and society. The technological transition involves not only technical changes but also societal changes, which include regulation, infrastructure, culture, industrial networks and practices. Moreover, the high dependency on fossil fuels is an obstacle to this transition process. Therefore, it is necessary to study the development of rooftop PV in Indonesia to investigate factors influencing the niche development, address the sociotechnical aspect of the process and identify barriers and opportunities for broader diffusion. In addition, considering various rooftop PV business models in Indonesia, it is necessary to investigate the role of business models in rooftop PV niche development.

Research methodology

This research uses qualitative analysis to investigate niche development by adopting two transition frameworks: multi-level perspective (MLP) and strategic niche management (SNM). Then, the business model's qualitative analysis is performed using the business canvas developed by Osterwalder et al. (2010). The analytical framework in this research is built upon integrating these three frameworks. First, the MLP framework is a foundation to explain the socio-technical dynamic between three levels: landscape level, regime level, and niche innovation. At the niche level, the SNM framework provides a comprehensive analysis of niche development. Meanwhile, the concept of the business canvas describes the activity of rooftop PV business actors. A case study was selected to gain a clearer understanding and analyse different rooftop PV business models in three provinces (Jakarta, Banten and West Java). The data collection was conducted by two methods: interviews with 15 respondents from different groups of actors and desk research, including academic literature, online newspapers, etc. The study aims to answer the question, "*How has the rooftop PV niche developed in Indonesia, and to what extent do business models influence niche development?*" .

Main findings

The results show that rooftop PV was first developed in the 1990s through a solar home system innovation pilot project in Sukatani village, West Java, supervised by three organisations (private companies R&S, DGIS and government agency) to support rural electrification in Indonesia. The learning process occurred in this pilot project (demonstration, public survey, and knowledge transfer) provided learning to the technical and policy development. Moreover, the success of this project created a positive expectation that attracted the government to be involved in the niche development. The government then announced two policies, which became the protected space for niche development and attracted more actors, including international donors, to provide funding (loan). However, in 1997, the financial crisis occurred in Asia. The financial crisis also led to economic issues and regime changes, such as government and policy changes. At that time, the development of rooftop PV experienced a setback. In the post-financial crisis, the niche development was mainly influenced by the government, especially after the announcement of the 17% renewable energy target and feed-in-tariffs mechanism, which led to the acceleration of rooftop PV adoption. In 2015, Indonesia's commitment to the Paris agreement encouraged the government to revise the RE target from 17% to 23%. The last landscape factor is the international and market pressure on industrial sectors to use green energy, which puts tension on industries to increase ESG scores by utilising rooftop PV.

Niche development of rooftop PV faces financial, institutional, policy, technical and awareness barriers. The business actors face financial obstacles of low financial profitability due to the absence of incentives and low electricity prices due to subsidising fuels. From the users' side, high upfront costs and long payback periods make users hesitant to use rooftop PV. Institutional barriers (e.g., permit from PLN and limitation of installed capacity by PLN) and policy (e.g., uncertain regulation and local content policy) hamper the rooftop PV development. Meanwhile, the local manufacturer's technical capability and low public awareness are other factors blocking the niche development.

The niche actors use three business models to overcome the adoption barriers of rooftop PV. The host-owned business model is developed to provide access for the consumer to be prosumers who can benefit from the feed-in tariffs. The third-party business model enables users to overcome the high-upfront cost barriers. Meanwhile, the cooperative business model operated by KUD emerged using grants in the early 1990s to facilitate the coordination of the increased participation of international donors, banks, suppliers and villagers. However, the role of the cooperative business models has decreased due to the economic crisis and the decline in the use of rooftop PV in rural areas.

Reflections

The integration of three frameworks in this thesis provides a thorough analysis of rooftop PV niche development in Indonesia, including the inter dynamic between landscape, regime and niche. Various information about the elements, learning process, barriers, opportunities, and information on business models are comprehensively explained through this analytical framework.

Recommendations

This study shows the importance of shielding strategies in supporting Indonesia's rooftop PV niche development. This thesis then recommends that the government should consider and systematically use the shielding concept in formulating approaches and regulations in developing the energy sector. Two

shield concepts from the SNM framework are active and passive shielding. The government should consider active shielding, such as reducing subsidies on fuel and subsidising the rooftop PV industry, designing the road map of rooftop PV development, increasing campaigns and adjusting the local content policy. On the other hand, the passive strategy could be conducted by executing the rooftop PV installation project in government-owned buildings.

Keywords: Rooftop PV, Indonesia, Strategic Niche Management, Multi-Level Perspective, Business Model

List Abbreviations

AESI : Solar Energy Association
Ah : Ampere hour
APAMSI : Association of Solar Manufacturers
Banpres : President-assisted project (Bantuan President)
BPPT : Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi)
DEN : National Energy Council
DGIS : Dutch General International Cooperation
FiT : Feed-in-Tarrifs
IESR : Institute for Essential Service Form
KEN : National Energy Policy (Kebijakan Energy Nasional)
KUD : Village Cooperative Unit (Kooperasi Unit Desa)
kW : Kilo Watt
kWh : Kilo Watt Hour
MEMR : Ministry of Energy and Mineral Resources (Energi dan Sumber Daya Mineral)
MLP : Multi-Level Perspective
MTRE3 : Market Transformation for Renewable Energy and Energy Fund
MW : Mega Watt
MW : Megawatt
NDC : Nationally Determined Contribution
NGO : Non-governmental Organisation
PLN : Perusahaan Listrik Negara
PPLA : Association of Rooftop Solar User
PV : Photovoltaic
REPELITA : Five-year National Development Plan (Rencana Pembangunan Lima tahun)
RUEN : National Energy General Plan (Rencana Umum Energi Nasional)
SDG : Sustainable Development Goal
SEF : Sustainable Energy Fund
SHS : Solar Home System
SNM : Strategic Niche Management

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CHAPTER 1 – INTRODUCTION

At the 2021 United Nations Climate Change Conference (COP26), Indonesia, which has committed to achieving 23% renewable energy in the energy mix by 2025 and reducing gas emissions by 29% by 2030, has set a new ambitious goal of having zero emissions in 2060 or sooner (IRENA, 2021). During 1990-2017, the emissions in Indonesia significantly increased by 140% and are forecasted to continue rising to 2030 under current policies. Several sectors, including the industrial sector (37%), transport (27%), and power sector (27%), contribute the most to the increased emissions (Climate Transparency, 2020). Indonesia's primary energy supply in 2021 comprised coal (37.62%), oil (33.40%), gas (16.82%), and renewable energy (12.16%), as shown in figure 1. The figures show that fossil fuels make up 88% of Indonesia's energy supply, including energy used for electricity generation, cooking, and transportation.

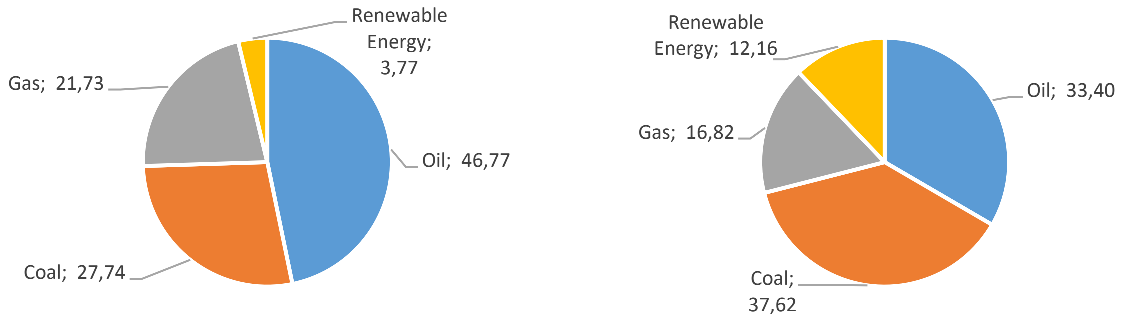

Figure 1 Primary Energy Supply in Indonesia, 2011 vs 2021 (MEMR, 2021a, p. 11)

For electricity generation, Indonesia has a severe problem of non-renewable energy dependency, which still relies on coal (62%) and natural gas (17%) in 2020 (IEA, 2022). In October 2021, the Ministry of Energy and Mineral Resources of Indonesia (MEMR) released a 10-years National Electricity Development Plan (RUPTL) to implement the energy transition toward zero-carbon 2060. It states that 51.6% of the target of new power or 20.923 Gigawatts (GW) sets come from renewable energy. The new installation 2021-2030 plan consists of coal (34.04%), hydro (25.59%), natural gas (14.37%), solar (11.53%), geothermal (8.26%), and other renewable energy (6.15%) (PLN, 2021b).

Indonesia has an enormous amount of non-renewable and renewable energy resources. The country was the primary producer of fossil fuel sources like oil and gas. However, the domestic production of several non-renewable energy sources, especially oil, has been declining in recent years. Due to increasing demand for oil as a primary energy supply and the declining domestic production, Indonesia has become a net oil importer since 2004 (EIA, 2020). Meanwhile, currently, Indonesia is known as one of the largest exporters of steam coal and liquefied natural gas (LNG). Although the country still exports LNG to meet the long-term contractual obligations, the government is forced to import LNG and start the construction of gas-transmission pipelines due to issues with gas exploration and higher domestic demand for natural gas (Amir et al., 2019).

The availability of renewable energy in Indonesia comes from various resources, including solar, geothermal, hydropower, biomass, and wind. However, the implementation of renewable energy potential is relatively tiny (Langer et al., 2021). According to International Energy Agency (IEA), by 2020, hydropower, geothermal, and biofuels power plant have generated 16.9% of the total electricity in Indonesia. In contrast, solar and wind power plant account for only 0.2% of power generation installed capacity. In total, renewable energy-based power plant accounts for around 17% of Indonesia's total electricity production in 2020 (IEA, 2022).

Despite the commitments and policies to develop renewable energy that the government has provided, Indonesia's current renewable energy deployment is not progressing according to plan (Langer et al., 2021). According to the press release by MEMR (2021c), the Minister of MEMR has said that Indonesia has only reached 11.2% of renewable energy in the energy mix by 2020 and needs concrete and planned effort to achieve the target of 23% renewable energy in 2025. The following table shows the composition of energy supply in Indonesia in 2021.

Table 1 Indonesia's energy supply in 2021 (MEMR, 2021a, p. 11)

Type of Energy	2021	Type of Energy	2021
Oil	33.40 %	**Solar**	0.05 %
Coal	37.62 %	**Wind**	0.07 %
Gas	16.82 %	**Other renewables**	2.52 %
Hydropower	3.09 %	**Biofuel**	4.41 %
Geothermal	1.99 %	**Biogas**	0.01%

Generally, the high demand for renewable and environmentally friendly resources is concentrated in several resources, such as solar energy. According to the RUPTL, Indonesia has a renewable energy potential of 443 GW, including 208 GW of solar energy (PLN, 2021b). However, solar energy utilisation is only approximately 0.05% of the total potential of solar energy (MEMR, 2017b). Solar panels, also known as photovoltaic (PV) cells, convert solar energy into electrical energy. Solar PV is essential in transforming the total energy mix in many countries. For instance, in a developed country such as Australia, rooftop PV produces approximately 45% of the peak load (Haryadi et al., 2021).

Although Indonesia has uniformly distributed solar potential across the country (Silalahi et al., 2021), PV cells face several challenges in the development process. The main obstacles to implementing PVs are land availability, land development & acquisition, geographical problem, substation capacities, and timely permits for onshore projects (Patil et al., 2017). With the enormous amount of roof availability, a rooftop PV system can be an alternative to applying photovoltaic cells to solve these problems.

Rooftop PV is photovoltaic cells installed on commercial buildings and residential rooftops. Rooftop PV system offers several advantages, including lower environmental impact and not requiring new transmission infrastructure. However, additional installation and maintenance costs will be borne by the owner. In addition, electricity grid management will become more complex due to the intermittent solar energy (Mohanta et al., 2015a).

In Indonesia, rooftop PV systems have become a National Strategic Project (PSN) to achieve a renewable energy target of 23% in 2025. Compared to other photovoltaic systems, rooftop PV systems are more popular due to the simplicity of installation and space availability, especially in urban areas. The installation number of rooftop PV significantly rose by more than 700% from 2018 until late 2020 (Haryadi et al., 2021). Moreover, in 2019, the installation of the rooftop PV system significantly increased by as much as 170% in the second quarter 2019 (Ummah et al., 2021). The following figure shows the number of rooftop PV customers in Indonesia.

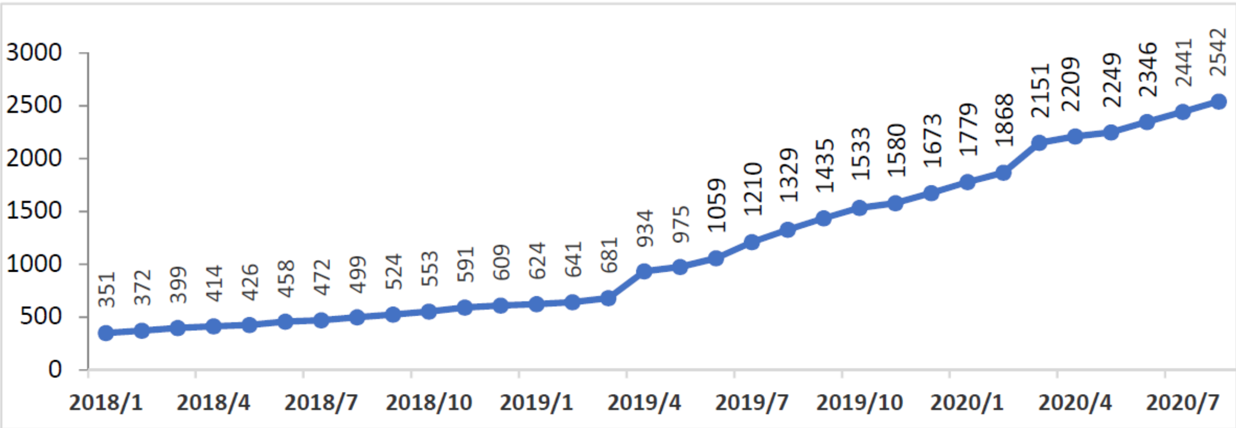

Figure 2 Number of rooftop PV customers in Indonesia (Haryadi et al., 2021, p. 2)

1.1 Problem Statement

According to Geels et al. (2017), it is necessary to accelerate the innovation and transition process to sustainable power plants to reduce gas emissions and achieve net-zero emissions. Geels also emphasised the importance of niche technology, in this case, low-carbon power plants, to be promoted as part or substitution of the current power generation regime (Geels et al., 2017). In the case of Indonesia, rooftop PV, due to the low installation rate (0.04%), humble contribution to electricity production (0.2%) and growing development initiatives, are considered niche technologies that need to be promoted to the current dominant regime.

Despite the abundant solar energy sources and previously mentioned opportunities offered by the technology, the growth of rooftop solar panels is considerably slow. Coal (62%) and natural gas (17%) are still dominant resources for generating electricity (IEA, 2022). The current situation is aligned with the statement by Geels (2002) that the new technology faces difficulty breaking through the current dominant sector because of the current regulations, infrastructure, networks and user practices that have been aligned.

The technological transition involves not only technical changes, but also societal changes such as user practices, regulation, infrastructure, culture and industrial networks (Geels, 2002). The transition to radically new technology like rooftop PV has not occurred quickly because the current sociotechnical elements are locked in with the present technology, such as coal-based and natural gas-based power plants. For instance, the Indonesian government has focused on utilising coal and gas resources to meet the growing electricity demand in the last decade. The dependency on coal and natural gas due to the technological capabilities, the economic impact and contribution to job creation is a barrier to the development of niche technology, rooftop PV in Indonesia (Bridle et al., 2018). Therefore, although Indonesia has rich solar energy potential, rooftop PV has hardly substituted the dominant coal and natural gas regime.

To achieve net-zero emission by 2060, it is crucial for Indonesia to rapidly scale up the transition of power generation to niche technologies such as rooftop PV. However, the transition is a complex process. It needs to consider various aspects such as niche technology developments, the sociotechnical system including organisation and actors, the current dominant regime, regulation and exogenous factors (Geels et al., 2017). Therefore, this report investigates the transition process and niche development of rooftop PV by considering multiple perspectives, including landscape development and the current dominant regime. This report also analyses the niche innovation strategy of rooftop PV in Indonesia.

Furthermore, according to Bidmon & Knab (2018), business models are needed to facilitate technological breakthroughs and promote novel technology from niche to regime level in the transition process. The business model behaves as a mediator between the niche technology and socio-technical regime and acts as a promoter of niche technology to enter the regime level (Bidmon & Knab, 2018). Therefore, it is also essential to perform research to examine the role of the current business model of rooftop PV in the energy transition in Indonesia.

1.2 Research Question

The main research question is:

"*How has the rooftop PV niche developed in Indonesia, and to what extent do business models influence niche development?"*

To help answer the main research question, the following sub-research questions are formulated:

1) What are the main actors and factors influencing rooftop PV development in Indonesia?
2) What are the main barriers and opportunities to rooftop PV development in Indonesia?

3) What type of business models are applied, and how has it influenced the rooftop PV niche development in Indonesia?
4) How can the niche market of rooftop PV in Indonesia be developed?

1.3 Societal Relevance

Indonesia's effort to eliminate climate change's impact on society faces several problems, including the slow transition towards renewable energy. This research aims to provide insight and recommendations to accelerate the transition to renewable energy by utilising the rooftop PV where broader society can directly participate. A comprehensive investigation of inter-dynamic in socio-technical elements in this research provides insights into barriers and opportunities that Indonesia faces. This insight serves as a guide for policymakers to transform the energy policy and regulation to support rooftop PV development. Moreover, this in-depth analysis in the current socio-technical elements can be used by business actors in the rooftop PV industry, such as private companies and entrepreneurs, to improve the existing business model and develop new innovative business models.

1.4 Alignment to Management of Technology

This research addresses a complex scientific study in a technological innovation context that fits the criteria of a Management of Technology master thesis. The scientific research focused on this thesis is regarding a complex niche management case of new technological innovation in sustainable transition, in which multiple actors with different interests and power surround the new technology diffusion. The technological context is centralised on the development of rooftop PV in Indonesia. Meanwhile, the management context is related to evaluating strategic niche management designed to facilitate the introduction and diffusion of new technology. The discussion about niche management strategy is mainly focused on the factors and activities influencing the entrepreneurial activity surrounding the rooftop PV diffusion, such as policy and the learning process. Moreover, the existing sustainable business model covering the innovation is discussed and analysed using the business model canvas. In the techno-social context, the current situation of Indonesia's rooftop PV development is analysed using scientific methods such as multi-level perspective and strategic niche management, which become a part of the main course in Management of Technology. Finally, this analysis identifies the opportunities and barriers to developing rooftop PV. Then, based on the investigation, policy recommendation for development strategy (e.g., regulation, policy, business model) is provided. For these reasons, this study is suitable for the Management of Technology thesis.

1.5 Thesis outline

This thesis is divided into nine chapters. The introduction of the research, problem statement, research question, the relevance to the societal research and alignment to the management of technology are described in this chapter. In the next chapter, chapter 2 explains the theory of multi-level perspective

(MLP), strategic-niche management (SNM), and business model. Moreover, chapter 2 provides reviews of the existing literature and an explanation of the knowledge gap. Subsequently, chapter 3 explains the research methodology used during the study.

To give a basic understanding of rooftop PV to the readers, the description of rooftop PV development in Indonesia, such as the history of Indonesia's rooftop PV, the explanation of rooftop PV technology, a business ecosystem of rooftop PV, and formal rules and policy, are provided in chapter 4. In the following chapters, chapters 5 and 6, the analysis result using MLP and SNM frameworks are explained, respectively. Furthermore, chapter 7 discusses the business model applied in rooftop PV development in Indonesia.

The analysis result of MLP, SNM and business models are discussed comprehensively in chapter 8. As the conclusion of the thesis, the answer to the research question and each sub-research question are provided in chapter 9. In addition, chapter 9 also presents the recommendation, the limitation of the study and advice for further research. The following diagram gives the overall outline of this thesis.

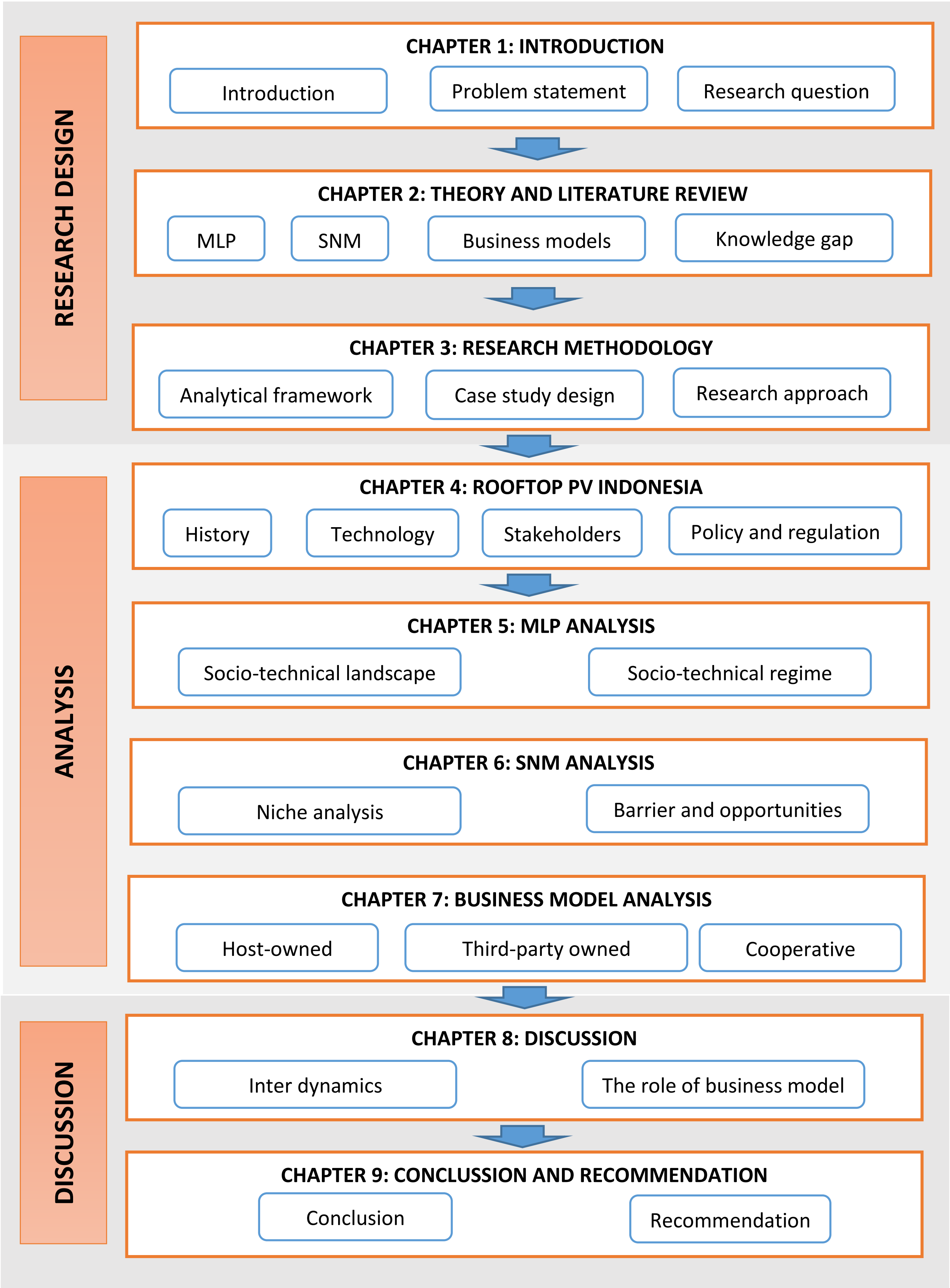

Figure 3 Thesis Outline

CHAPTER 2 – THEORY AND LITERATURE REVIEW

This section explains the theory and literature review used during this research. The articles used were obtained on Google, Google Scholar and Scopus. First, to answer the first and second sub-questions regarding socio-technical dynamics, a qualitative analysis will be carried out using a transition framework: multi-level perspective (MLP) and strategic niche management (SNM). The description of the multi-level perspective framework as a common method to analyse the transition process is provided. Subsequently, the strategic niche management framework used to analyse the niche-innovation process is reviewed. Next, a qualitative business model analysis is discussed to answer the third sub-research question. The explanation of the sustainable business model and business canvas is provided in this section. Thirdly, an overview of existing literature on SNM framework in a developing country, SNM framework application in Indonesia, and business model contribution to socio-technical transition. Finally, an overview of the knowledge gap for this thesis is explained.

2.1 Multi-level perspective (MLP)

Geels (2002) defines technological transitions as the significant technological change in the societal configuration. The technological transition involves changing various elements such as technology, regulation, networks, infrastructure, etc. In other words, the analysis of technological transition not only considers the technological change (production side) but also considers various perspectives, including the user and market side (functional side). To make a successful technological transition, users must adapt to the new technologies in their practices, routines and organisations, including adjustment and learning (Geels, 2004). In sustainable energy transition cases, the involvement of various actors with different interests creates a complex process. The energy transition is more than merely a technological shift, but it also needs to consider aspects such as the socio-technical change, including organisation and actors, dominant regime, regulation and exogenous factors (Geels et al., 2017; Loorbach et al., 2017).

The multi-level perspective is commonly used as a theoretical framework to analyse these different elements to explain the phenomenon of the technological transition from current sociotechnical regimes to a niche technology. To illustrate the transition, MLP has three heuristic levels: macro-level (socio-technical landscape), meso-level (socio-technical regime) and micro-level (niche-innovation). Figure 4 shows the typology of MLP based on the timing and nature of multi-level interactions (Geels, 2002; Geels & Schot, 2007).

At the macro level, the socio-technical landscape consists of exogenous factors in the system that directly influence the activity at the meso-level (regime) and micro-level (niche) (Geels & Schot, 2007). The exogenous factors can be global climate change issues, cultural changes, economic crises or unprecedented events such as wars and pandemics. These exogenous factors are autonomous and cannot be influenced by the regime and niche actors (Bidmon & Knab, 2018).

The socio-technical regime at the meso-level refers to a system, routines, regulation, standards, and lifestyle maintained by related actors that dominantly control the societal system (Geels & Schot, 2007). Sociotechnical regimes are dynamically stable because they result from continuous interaction and are maintained by regime actors (Bidmon & Knab, 2018). In figure 4, Geels (2002) distinguished socio-technical regime into seven dimensions: technology, marker (user practices), policy, techno-scientific knowledge, industry structure, culture (technological symbolic) and infrastructure. These seven dimensions influence the transition process of new technology. In addition, the seven dimensions are different but interrelated, which may affect each other (Geels, 2002).

At the micro-level, niche innovation refers to the new technology that emerges in the niche market consisting of small networks and dedicated actors (Geels & Schot, 2007).

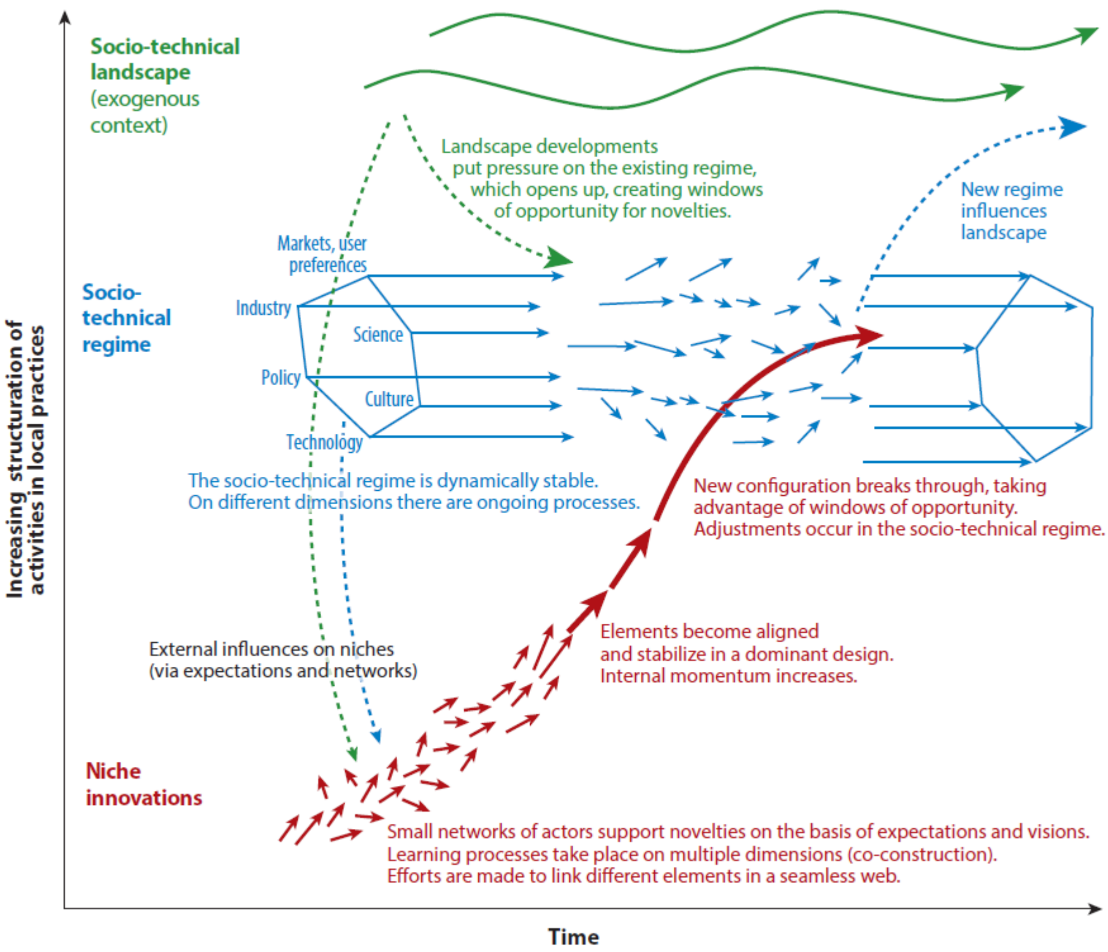

Figure 4 Multi-level perspective on transition (Loorbach et al., 2017, p. 606)

In the MLP framework, the interaction between the three levels (landscape, regime and niche innovation) is critical in the transition process. Figure 4 show several interactions within the three levels in the transition process (Geels & Schot, 2007). First, the exogenous factor in the landscape level put pressure on the current regime, destabilising the existing dominant system. This pressure from the landscape level opens up and leads to a window of opportunity for niche innovation. In addition, the landscape level also influences niche innovation by managing expectations and supporting social networks within the niche. Secondly, the existing regime affects the transition process by influencing niche innovation through the seven dimensions described before. Lastly, the development of niche innovation increases the momentum of transition. The niche development can be performed through a learning process, increasing the number of influential groups and improving price/performance. Therefore, the MLP framework argues the transition process rresults from the interaction within these three levels (Geels, 2002)

2.2 Strategic niche management

The previous MLP framework explains that the diffusion of niche innovation requires niche innovation to interact with the socio-technical landscape and socio-technical regime. To extensively analyse the diffusion, there is a requirement to analyse diffusion from the external context and niche-internal process. In this case, the strategic niche management framework complements the MLP framework by analysing the internal process of niche innovation (Turnheim & Geels, 2019). Generally, strategic niche management (SNM) is an analytical approach used to review and analyse the deliberate process of managing innovative niche technologies (Linda M. Kamp & Vanheule, 2015a). This theoretical approach will provide an analytical framework for studying the sociotechnical dynamics of the technology's internal environment. Moreover, according to many scholars, SNM was developed to discover methods to manage innovation with long-term goals such as sustainability incompatible with current infrastructure, regulation, user knowledge, etc. (Schot & Geels, 2008).

According to SNM scholars, the niche internal process in the SNM framework can be distinguished into three properties: shielding, nurturing and empowerment (Smith & Raven, 2012). These processes are described below.

1) Shielding

With the unstable sociotechnical configuration and low performance in the initial stage, radical innovation struggles to compete in the mainstream market competition. Thus, the shielding strategy is necessary to protect the innovation from the market selection criteria (Turnheim & Geels, 2019). The SNM literature defines sociotechnical niches as temporary 'incubation rooms' or 'protected spaces' to shield the innovation with different selection criteria (Geels & Schot, 2007). Smith & Raven (2012) mentioned radical innovation requires protected space to protect them from the prevailing selection pressure. Moreover, the protected area will provide room for configuration and development of radical innovation.

Smith & Raven (2012) further categorised protected space into two types: active shielding space and passive shielding space. Active shielding space is a space resulting from deliberate and strategic intervention organised by policy and non-policy actors. For example, the policy actors can arrange the shielding through technology policies and financial incentives. Meanwhile, the non-policy actors can organise bottom-up or civil-society initiatives like ‘Wij Willen Zon’ initiatives in the Netherlands. On the flip side, the passive shielding space is a generic space resulting from the advocation that will precede the mobilisation of innovation. An example of passive shielding space is a geographical space, such as an area where the invention allows to develop without competition with the mainstream system.

2) Nurturing

Smith & Raven (2012) define nurturing as an activity and process reinforcing the development of niche-innovation development. Early SNM scholars distinguish the nurturing process in the SNM framework into three development mechanisms: (1) the articulation and shaping of expectations, (2) the building of social networks and (3) learning processes (Turnheim & Geels, 2019).

The articulation and shaping of expectations

Expectations are considered a crucial factor in the development of a niche because it guide the development process, attract new resources such as new actors, and affect design choices. To contribute to a successful technology niche, the expectation need to be built to be more robust (shared by multiple actors), more specific (to provide clear direction for the technology development) and higher quality (validated content of the ongoing project) (Schot & Geels, 2008).

In SNM, the expectation around the technology niche will be evaluated. The evaluation will be conducted not only for the actors’ expectations from inside the niche (internal expectation) but also from outside the niche (external expectation). Questions regarding actors’ awareness and their expectations (positive or negative) about the technology will be answered by this evaluation. The result will be used as insights for the development process (Linda M. Kamp & Vanheule, 2015a).

The building of social networks

Building social networks is another critical factor in niche development because it can provide more resources and actors, facilitate the interaction between actors, enhance the learning process, and maintain the sustainability of the development process (Linda M. Kamp & Vanheule, 2015a). Two characteristics of social networks that are important to contribute more to niche development:

- Composition of social networks should be broad
  The network composition is closely related to the number and type of stakeholders involved in the development process. The composition is essential for developing niche technologies because multiple stakeholders will enable developers to articulate various views and voices regarding the niche. Moreover, social networks will allow developers to broaden their cognitive frames and facilitate learning (Schot & Geels, 2008).

- Alignment of social networks should be deep

  The alignment of social networks can be defined as the extent to which the vision, expectations and strategies of the relevant actors align with niche development (Linda M. Kamp & Vanheule, 2015a). In developing a niche technology, the alignment of social networks is critical because it will affect the development process, such as the mobilisation of resources within the organisations and the networks (Schot & Geels, 2008)

Learning processes

The learning processes are defined as accumulative processes in which actors collect and align relevant information of technology, market and other factors (Linda M. Kamp & Vanheule, 2015a). More information contained in the process will allow the learning process to contribute more to niche development (Schot & Geels, 2008). This contribution occurs by influencing expectations and aligning them. Kamp & Vanheulu (2015) mentioned five aspects related to learning processes: technical and infrastructure development, industrial development and environmental impact, development of user context, and government policy and regulatory framework (Linda M. Kamp & Vanheule, 2015a).

3) Empowerment

Smith & Raven (2012) highlight empowerment as the process of determining whether a niche will force the regime change or niche innovation itself to adapt to the mainstream selection environment. SNM scholars define empowerment as a political and negotiated process involving a group of coalitions that build narratives to justify the regime change or maintain the regime (Turnheim & Geels, 2019). The empowerment process is categorised into two types: (1) fit and conform empowerment and (2) stretch and transform empowerment. Fit and conform empowerment refers to the process of adjusting the niche innovation to be compatible with the selection environments. On the other side, stretch and transform empowerment is the process of restructuring the current regime to fit with the niche innovation.

2.3 Review of existing research studying SNM framework in a developing country

This section reviews the existing literature studying sustainable transition in developing countries using the SNM framework. The following keywords*: "strategic-niche management"*, *"developing country"*, and *"global south"* are used. The literature search was performed in Google Scholar and Scopus. There are twelve works of literature studying transition in developing countries using the SNM framework. Table 2 presents the author's name, topics, and research findings of each literature.

Table 2. Literature of SNM framework application on energy transition in developing countries

Author	Topic	Findings
(Elmustapha et al., 2018)	Comparative studies of Lebanon's two renewable energy market development (solar photovoltaic and solar thermal energy).	SNM is used to compare two renewable energy market development in developing countries. One niche development (solar thermal) influenced another niche development (solar PV). Moreover, International donors play a crucial role in niche development in Lebanon.
(Elmustapha & Hoppe, 2020)	A case study of solar energy niche development in Lebanon	Integration of SNM framework and business model in promoting niche solar energy development.
(Linda M. Kamp & Vanheule, 2015a)	A case study of wind turbine development in Kenya	SNM and MLP are used to analyse the bottlenecks for niche development
(Mirzania et al., 2020)	Comparative studies of the dissemination of concentrated solar power in South Africa and the United States	SNM compares niche development in a developing country and a developed country. Support scheme from international actors has a considerable influence in South Africa; meanwhile, government support schemes have become the main factor in the niche development of CSP in the United States.
(Linda Manon Kamp & Bermúdez Forn, 2016)	A case study of emerging domestic biogas in Ethiopia	The challenges for the dissemination, including financial instability, poverty, illiteracy, and lock-in effect on current technology, are analysed using SNM.
(Rehman et al., 2010)	A case of the Uttam Urja project (photovoltaic lighting technologies in rural areas) in India	SNM framework is used to identify critical success factors or the niche experiment. Branding, marketing and funding schemes from banks are considered new factors that need to be added in SNM studies.
(Fatimah, 2020)	A case study of Jatropha fuel development in Indonesia	A combination of SNM framework and function of the innovation system is adopted to analyse the heterogeneity of actors
(van Eijck & Romijn, 2008)	A case study of biomass energy experiments in India	Use learning-based approaches to investigates the suitability and limitations of the SNM framework
(Salé & Dewes, 2009)	A case study of Jatropha fuel development in India and Africa	SNM is applied to analyse the critical factor to develop Jatropha fuel, including the participation of all stakeholders. Moreover, a certifications system is required in developing biofuel.
(Drinkwaard et al., 2010)	A case study of Hydro projects in Bolivia	Using a learning-based perspective to analyse additional factors as complements for SNM
(Verbong et al., 2010)	Biomass gasification case study in India	The application of the SNM framework to analyse the development and implementation of niche biomass
(van Eijck & Romijn, 2008)	Prospect of Jatropha biofuels development in Tanzania	SNM and MLP application discuss the socio-techno transition of Jatropha biofuels in Tanzania

There are three observations that can be understood from the literature listed in the preceding table. First, the number of works of literature studying the SNM framework application in developing countries is limited. Although not all literature is included in table 2, the number of publications related to SNM application in developing countries is small compared to developed countries (Xue et al., 2016). Most of the main transition frameworks, including SNM and MLP, have widely been used in developed countries to study the socio-technical transformation (Wieczorek, 2018). Moreover, due to the complexity of socio-techno dynamics in developing countries, adopting the original SNM framework to analyse the sustainable transition network in developing countries is limited (Romijn et al., 2010). Therefore, it can be considered necessary to increase publication on the application of SNM in developing countries because the amount of literature published is minimal.

The second observation is the various new perspective discovered from the case study in developing countries that can be added to the SNM framework. For instance, Rehman et al. (2010) 's recent findings on the importance of branding, marketing, and a financial loan from a bank in novel PV lighting technology development in India. The article explains that branding and marketing help articulate the technology to potential users. Moreover, while many SNM publications address public funding as space protection for niche technology, the articles explain that financial support from banks plays a crucial role in developing countries like India (Rehman et al., 2010). Another new perspective can be found in Elmustapha et al. (2018). The paper discusses the importance of multinational support, including International donors, in disseminating new technology in developing countries (Elmustapha et al., 2018). Lastly, according to Angelina et al. (2018), the role of government in developing countries is considered a vital part of niche development. The perspective on the role of government is one of the main differences between niche development in a developing country and a developed country (Angelina et al., 2018). In this case, a more recent SNM framework is insufficient to discuss the niche development process in developing countries (Salé & Dewes, 2009). Accordingly, more case studies in a developing country can shed light on various new perceptions of the SNM framework.

The final observation is the SNM framework's function in studying transition in developing countries. In Elmustopha et al. (2018), the SNM framework is used to analyse two niche technology developments in the same region. The article found that the development of one niche technology (solar thermal) can affect other niche technology development (solar PV). Another application of the SNM framework is a comparative study tool between the niche innovation development in a developed country and a developing country. The comparative studies show the difference in the government's role in niche CSP technology development between South Africa and the United States (Mirzania et al., 2020). Moreover, Elmustapha & Hoppe (2020) discuss that the SNM framework can contribute to the business model to facilitate the niche development (solar energy) into the regime. The article compares different business models by using the insight from SNM. The result shows that microfinance, business startup, knowledge transfer, and community empowerment play an essential role in the business model of niche innovation in developing countries like Lebanon.

In light of these three observations (gaps in current literature, various additional perceptions resulting from developing countries' case study and the application of SNM framework), the thesis research examining the niche development of rooftop PV in Indonesia will contribute to adding a new perception on SNM framework and revealing the barriers of rooftop PV development based on SNM.

2.4 SNM framework approach in Indonesia

This section describes a literature review on applying the SNM framework in Indonesia. The literature search is carried out using keywords *"Strategic niche management"* and *"Indonesia"* in Google Scholar and Scopus. Table 3 presents a list of publication authors, topics, and findings.

Table 3. Literature of SNM framework application in Indonesia

Author	Topic	Findings
(Fatimah, 2020)	A case study of Jatropha fuel development in Indonesia	A combination of SNM framework and function of the innovation system is adopted to analyse the heterogeneity of actors
(Angelina et al., 2018)	A case study of the innovative urban transportation system (BRT) in the capital city of Indonesia (Jakarta).	SNM is applied to analyse the development of niche transportation systems in capital cities of a developing country. The result emphasises the government's vital role as the main promotor of niche. Moreover, the promotions to articulate the new technology are essential.

Only two publications discussing the SNM framework adoption can be found in Indonesia's case. One publication by Fatimah, which is also included in table 2, discuss the combination of the SNM framework and function of the innovation system in analysing the transition process. Another publication by Angelina (2018) studying sustainable transition in new transportation systems using SNM application can be found (Angelina et al., 2018). This show that publication on the SNM framework in Indonesia is very limited. In addition, Langer et al. (2021) stated that one of the research gaps for Indonesia to achieve its renewable energy potential is the lack of publications (Langer et al., 2021). Therefore, to support the achievement of the renewable energy goals, the research thesis will contribute to increasing the number of publications.

2.5 Role of business model in the transition process

A business model is a conceptual approach that describes how a company does business and can be used as an explanation of strategic matters, including product/service value proposition, market segmentation, distribution channels and cost structures (Osterwalder et al., 2005). According to Teece (2010), business models translate how firms create product/service that has economic value by combining available resources and capabilities. Moreover, it mentions that the business model merely describes the organisational and financial architecture and assumptions about market needs and customer and competitor characteristics (Teece, 2010).

Related to sustainability, the business model is essential to provide an integrated approach to synchronising technological and social innovation with sustainability to reach long-term sustainability (Bocken et al., 2014). The sustainable business model is a term used by many studies as a business model that creates a competitive advantage by offering higher quality value and contributing to sustainable development (Lüdeke- Freund, 2010). The business model is commonly described using the business model canvas developed by (Osterwalder et al., 2010). Figure 5 present the business model canvas framework.

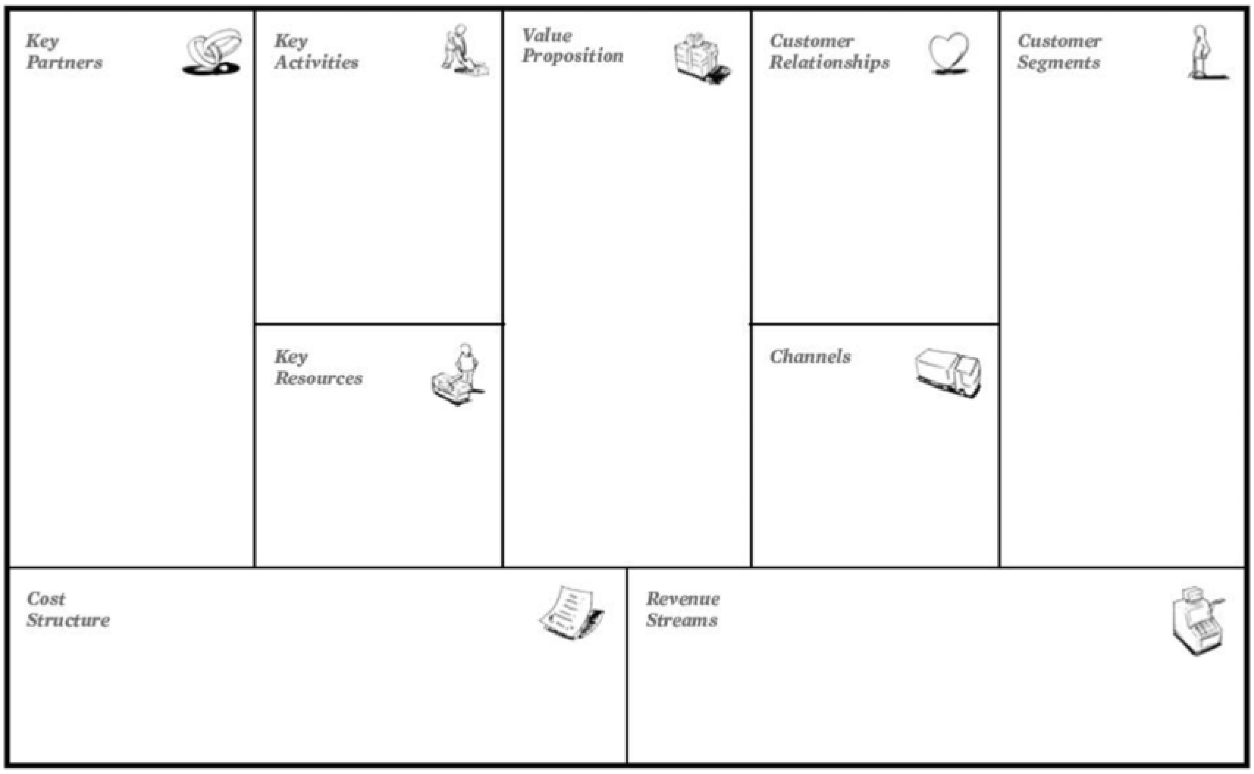

Figure 5. Business Model Framework (Osterwalder et al., 2010)

The business model canvas consists of nine building blocks. The nine-building blocks of the business model framework describe bellow:

- Key Partnerships: The description of the network of partners and suppliers involved in the value chain of business work.
- Key Activities: List the essential things a company needs to do to operate the business.
- Key Resources: The essential requirement in the business model operation, including financial, materials or people
- Value Proposition: The description of the value of product and service that company offers to a particular consumer

- Customer Relationships: The description of what type of relationship the company establish with customers
- Customer Segments: The customer segments building block defined the different groups of customers based on needs, behaviours, financial or other attributes.
- Channels: Description of distribution channel that company have in delivering its value proposition
- Cost Structure: The description of all incurred during the business operation.
- Revenue Streams: The revenue stream building blocks represent the income company generates.

In socio-technical transition, Bidmon & Knab (2018) explain that business models have crucial roles in socio-technical changes, including as mediators between socio-technical regimes and niche innovation and as a promoter of niche innovation for a breakthrough to regime level. In the paper, the role of the business model in sustainable transition can be categorised into three parts as follows (Bidmon & Knab, 2018).

1) Business models as part of the socio-technical regime
   Bidmon & Knab (2018) argue that business models as part of socio-technical regime articulates shared visions, expectations, rules and routines in the regime system. The business models reinforce the regime's dynamic stability by acting as a point of reference in the interaction between actors. In this case, the existing business model creates a more substantial barrier to entry for niche innovation in socio-technical transition (Bidmon & Knab, 2018).
2) Business models as intermediates between technological niche and socio-technical regime
   As an intermediary between niche innovation and socio-technical regime, many transition studies regard business models as conceptual tools for promoting niche innovation to enter the regime level. Three sub-processes have been identified that need to be taken into account in this phase (Bidmon & Knab, 2018):
   - Business models articulate the visions and expectations that synchronise various activities by actors
   - Business models reinforce learning processes and promote knowledge transfer to improve the performance of niche-innovation
   - Business models support niche innovation in developing social networks
3) Business models as a non-technological niche innovation
   For niche innovation to enter and replace the regime level, the stability of the niche system needs to be improved. Through its function as an articulation of visions and expectations, the reinforcement learning process, and the building of social networks, Bidmon & Knab (2018) consider the business model a non-technological innovation that can increase the stability of niche systems.

2.6 Review of existing literature studying business model contribution on sociotechnical transition

According to Bidmon & Knab (2018), most of the literature that discusses sustainable transition focuses on technological innovation. Only a few works of literature discuss non-technological innovation, which is also an essential part of the success of the transition process. Scholars and practitioners regard business models, which help translate the non-technological innovation, as a necessary factor in achieving regime change. Although the contribution of the business model on regime change is acknowledged, there is little research studying the exact role of business models in the transition process (Bidmon & Knab, 2018).

Boons and Lüdeke-Freund (2013) paper discusses the linkages between business model and sustainable transition. The article explains that examining a business model is essential to understanding the actual process of a successful company bringing novel technologies to the market. However, the amount of literature explaining business models in sustainable transition is minimal. Therefore, the paper emphasises the importance of further investigation of interrelationships between business model and sustainable transition (Boons & Lüdeke-Freund, 2013).

Furthermore, in a recent study, the lack of literature on business model contribution in sustainable transition is mentioned by Elmustapha and Hoppe (2019). The paper recommends conducting further research on business models in sustainable transition in multiple developing countries (Elmustapha & Hoppe, 2020). Given the research gap in which the literature explaining the interrelationships between business models and the sociotechnical transition is very limited, additional insights from studying business models in the sustainable energy transition will contribute to filling this gap. Therefore, this thesis analysing the contribution of the business model of rooftop PV niche will contribute to adding to the literature on business models in sustainable transition.

2.7 Knowledge gap

According to aforementioned, several knowledge gaps have been found in the current literature. First, the limitation of the original SNM framework in explaining the transition process in developing countries. Several studies show that several new perspectives can be added to the SNM framework. However, the number of those studies is considerably limited. Secondly, the number of publications regarding SNM framework application in Indonesia is very limited. Only two literatures can be found. Langer et al. (2021) emphasise that lack of publications is one of the obstacles for Indonesia to achieving its renewable energy potential. Lastly, there is a lack of publication on the role of business models in sustainable transition. Elmustapha & Hoppe (2020) suggest conducting more research on sustainable transition business models in various developing countries. Therefore, this research will contribute to adding to the literature on the SNM framework in developing countries, particularly in Indonesia, and literature on the business model in the transition process.

2.8 Conclusion

According to those mentioned earlier, the MLP and SNM frameworks are standard analysis frameworks used to explain the transition phenomenon in technological transformation. The MLP framework is used to analyse the external factor such as landscape, regime and niche innovation, influencing the transition process. Meanwhile, the SNM framework explains the niche innovation's internal activity, including the analysis of the shielding process, nurturing approach and empowerment. The combination of MLP and SNM frameworks covers the external factor and internal activity that influence the transition process towards niche innovation. Moreover, the business model consisting of nine-building elements describes various actors' business strategies and activities surrounding the niche innovation. Therefore, these three frameworks (MLP, SNM and business model) are incorporated as an analytical framework to comprehensively describe the transition process of the energy sector in Indonesia toward rooftop PV. The conceptualisation analytical framework for this study is explained in the following chapter.

Lastly, the literature review of the existing academic literature shows three knowledge gaps that can potentially be answered through this study. Those knowledge gaps are: (1) the limitation of the perspectives in the original SNM framework, (2) the limitation of SNM framework publication regarding the Indonesia case and (3) the lack of literature explaining the role of business model in sustainable transition.

CHAPTER 3 – RESEARCH METHODOLOGY

This section is an overview of the research methodology and design used during the present thesis. This research methodology was designed to examine the niche development of rooftop PV in Indonesia. First, this study combined explanatory and exploratory research to answer the main research questions. Sekaran & Bougie (2016) define exploratory research as a method used to investigate a problem that is not clearly defined. While explanatory research is a method to explain current phenomena in real-life situations. In this thesis, exploratory research was conducted to answer the main research question regarding "*How has the rooftop PV niche developed in Indonesia?*". The exploratory research was carried out to answer the first and second sub-research question. On the other hand, explanatory research was conducted to answer the main research question regarding "*To what extend do business models influence niche development?*". The third and fourth sub-research questions were answered through the exploratory research.

According to Sekaran & Bougie (2016), exploratory and explanatory research can be implemented through a qualitative approach to collecting the data. In this thesis, a case study was used as the main research method to examine the phenomenon of the sustainable transition toward rooftop PV in Indonesia. The first part of this section explains the conceptualisation of the analytical framework used during the analysis. Three theoretical theories explained in the previous chapter (MLP, SNM and Business model) are combined and explained in the analytical framework. Moreover, the case study description, geographical boundary, and data collection are explained as follows.

3.1 Analytical framework

This section outlines an analytical framework designed as a systematic model for analysing rooftop PV development. The analytical framework combines the three theoretical frameworks (SNM, MLP and business model framework) discussed in chapter 2. The SNM framework, which is a theoretical framework used to analyse the social dynamics of niche technology, will be the main conceptual framework for analyzing rooftop PV development. Meanwhile, the MLP framework will be an additional framework used to analyse social dynamics outside the niche technology, including socio-technical landscape and current regimes. Furthermore, business model framework by Osterwalder et al., (2005) will be used to present the activities by actors around rooftop PV, including actors in niche innovation level and regime level. Figure 6 present the analytical framework for this study.

The analytical framework uses the MLP to broadly identify three heuristic levels: landscape, regimes and niche (Geels & Schot, 2007). In the niche levels, the SNM framework will be used to investigate three important concept in developing niche technologies, namely shielding, nurturing, and empowerment (Smith & Raven, 2012). Figure 6 shows the position of these three perspectives and how they affect the diffusion of rooftop PV from niche innovation level to regime level. Subsequently, three roles of business models in societal transition discovered by Bidmon & Knab (2018): business models as part of a regime, as an intermediary between a niche and a regime, and as a non-technological niche innovation are adopted to analyse the influence of current business model PV development.

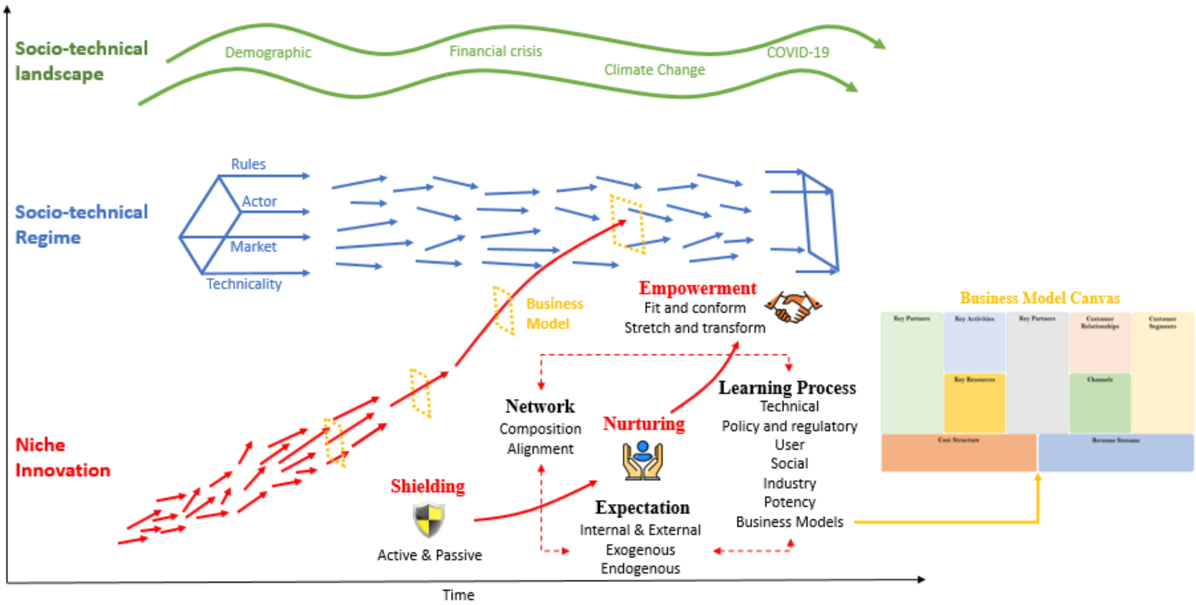

Figure 6 Integrated analytical framework of the MLP, SNM, and business model (Adapted from (Geels & Schot, 2007 Osterwalder et al., 2010; Smith & Raven, 2012; ; Kamp & Vanheule, 2015; Loorbach et al., 2017; Hakim, 2021)

Detailed descriptions of how the analytical framework described above is used are provided in the following section:

3.1.1. Niche-innovation analysis

Niche-innovation analysis on rooftop PV development adopts the SNM framework to systematically analyse the development processes. Three main processes are examined: niche nurturing, niche shielding, and niche empowerment. The description of each process is provided as follows.

1) **Niche nurturing**

As explained in the chapter 2, the nurturing process are distinguished into three processes: the articulation and shaping of expectation, social network formation and learning process.

➢ **Articulation and shaping of Expectation**

This study will evaluate the expectation around the technology. Based on Kamp & Vanheule (2015), the evaluation will be carried out for the actors' expectation from inside the niche (internal expectation) and for the actors' expectation outside the niche (external expectation). The evaluation will be performed by interviewing the internal actors and external actors. Questions regarding actors' awareness and their expectation (positive or negative) will be asked during the interview.

- **Social networks formation**

  This study will investigate two factors regarding social network formation, namely composition of actors and the alignment between actors. To understand the formation of social networks around the rooftop PV development, identification of the composition of actors around rooftop PV is conducted. This identification process will be carried out by conducting desk research and interview. In addition, the alignment and social dynamics between actors is analysed and is mapped. The question regarding who is the main actors involved and the alignment with another actors will be asked during interview.

- **Learning process**

  The learning process in this study will be examined according to five aspects of learning developed by Hoogma et al. (2002) and two aspects of learning developed by Kamp & Vanheule (2015). The five aspects mentioned by Hoogma et al. (2002) are technical development and infrastructure, government policy and regulatory framework, user context development, social and environmental impact, and industrial development. In addition, two aspects of learning added by Kamp & Vanheule (2015) are solar energy potencies and viable business models. The data collection regarding learning process will be carried out by interview. The seven aspects is explained as follows.

  - Technical development and infrastructure

    The learning process involves several studies on technology specifications, complementary technologies and infrastructure required for the diffusion of rooftop PV (Linda M. Kamp & Vanheule, 2015a). This study will investigate the learning process needed to gather feedback used to improve rooftop PV dissemination to the wider network (Elmustapha et al., 2018).

  - Government policy and regulatory framework

    The learning process includes policies and regulations related to the rooftop PV diffusion. Moreover, this study will also look into learning process about the incentives provided by the government to support the dissemination.

  - User context development

    Learning about the development of user context refers to the learning process about user needs, characteristics and obstacles faced by the user in adopting rooftop PV. This learning process identifies the potential risk and user desirability about the niche technology.

  - Social and environmental impact

    This can be categorised as a learning process related to the impact of the rooftop PV on society and the environment.

  - Industrial development

A learning process involving the business ecosystem and value chain of rooftop PV. Manufacturers of main technology and complementary technologies will be investigated.

- Solar energy potencies

  The evaluation will measure to what extent the stakeholders involved understand the availability of solar energy resources.

- Viable business models

  This learning process is related to creating a business model that enables the dissemination of rooftop PV. This learning process on business model will also be analysed.

2) **Niche shielding**

   This study will analyse the two types of shielding mentioned by Smith & Raven (2012): active and passive shielding. Regarding active shielding, the niche space provided by policy actors such as financial support and technological policies will be examined. Moreover, the niche space by non-policy actors such as the bottom-up movement will also be explored in this study. Furthermore, the passive shielding will also be investigated by exploring examples by Smith & Raven (2012): geographical spaces, institutional spaces, general public support and the environmentalist milieu movement.

3) **Niche empowerment**

   Smith & Raven (2012) distinguish two types of niche empowerment: (1) empowering to fit and conform and (2) empowering to stretch and transform. Based on the two types of empowerment, this study will examine several factors that encourage the development of rooftop PV. First, regarding the empowerment to fit and conform, this study will analyse what factors have been implemented to increase the competitiveness of rooftop PV in the current electricity regimes. Secondly, regarding the empowerment to stretch and transform, this study will explore the adjustment that has been made in the current electricity regimes to support the rooftop PV dissemination.

3.1.2. Regime analysis

The analysis at the regime level will focus on the current electricity regimes, which will be examined by using three interrelated dimensions: (a) network of actors; (b) formal rules; and (c) technical elements (Verbong & Geels, 2007). First, the analysis of the actor's network will be conducted by stakeholder analysis. Stakeholders, including dominant utility companies, governments, private companies and users, will be analysed. Second, a formal regulatory analysis will be conducted by identifying the applicable laws and regulations. Finally, this thesis will analyse the technical elements consisting of technology and science in the field of electricity today. This analysis at regime level will be carried out mainly through the desk research method.

3.1.3. Landscape analysis

Landscape-level such as environmental awareness, the Paris climate agreement and shortage of non-renewable resources will be analysed in this study. Data related to the landscape will be collected through desk research and interviews.

3.1.4. Business model analysis

The business model analysis will focus on the three roles of business models in transition developed by Bidmon & Knab (2018): (1) as part of a socio-technical regime; (2) as an intermediary between niche and the socio-technical regime; and (3) non-technological innovation. First, identify the business model of the actors at the regime level that will be conducted. For example, in the case of Indonesia, the business model of PLN as the dominant actor in the utility sector will be analysed. Subsequently, identify the business model of actors at the niche level, such as the business model of rooftop PV providers and technology manufacturers. This analysis is necessary to understand the influence (positive or negative) of the existing business model on rooftop PV dissemination. Finally, the identified business model will be presented by using the business canvas developed by Osterwalder et al. (2005).

3.2 Case study design (multiple case)

A case study is among the commonly used methods to gain a clearer understanding of a problem in a real-life context by examining the current phenomenon from various angles and perspectives (Sekaran & Bougie, 2016). This thesis used a case study to investigate Indonesia's recent rooftop PV development from different points of view using multiple data collection methods (explained in section 3.5.). Here, the main interest of this study was to study the dynamics operating in various groups involved and the factors influencing the development of rooftop PV in Indonesia. The unit analysis of the case study is rooftop PV. Although it can be classified into two types, namely on-grid rooftop PV and off-grid rooftop PV, this study concurrently examined the development of these two types of rooftop PV (Singh, 2018).

To obtain a clear view from different perspectives, the case study was designed in a multiple-case scenario. Specifically regarding the rooftop PV business models, several cases from different stakeholders or groups involved were studied. Given the limitations of time, cost and human resources in this study, the sampling method was carried out to select the right and specific stakeholders or groups involved as representative. The sampling method used in this study was judgment sampling. Judgment sampling was used to find expertise that is able to provide the information needed by the researcher. In addition, judgment sampling is widely used when the number of people with information is limited (Sekaran & Bougie, 2016). In this study, several state-owned and private companies were identified operate in rooftop PV business ecosystem in Indonesia. However, due to the limitation of access to approach the expertise, the principal investigator selected several conveniently reachable interviewees.

Some of the actors and potential business models mentioned in the following table is discussed in this study—table 4 presents actor type and type of business model. The prospective respondent was analysed in detail in the stakeholder analysis section.

Table 4 List of type of business model as case study

No	Actor Type	Type of Business Model
1	State-own company	Incumbent Business Model
2	Private Firms	Host-owned Business Model
3	Private Firms	Third-party-owned Business Model
4	Private Firms	Cooperative Business Model

3.3 Geographical boundary

Due to the limitation of research duration, this thesis research is limited based on geography. To determine which boundary will be the focus of this study, two parameters have been considered based on several literatures. The first parameter is the potential of the rooftop PV market. According to Institute for Essential Services Reform (IESR), market potential is determined based on the technical potential and realistic market potential. Technical potential refers to the technical feasibility of installing solar PV based on the availability of residential roof space. Meanwhile, the realistic market potential refers to the willingness and ability of customer to purchase rooftop PV. Realistic market potential is influenced based on several factors including market price and availability, public information, and supportive polices. The top ten provinces with the highest market potential for rooftop PV are East Java, West Java, Central Java, North Sumatera, Banten, Jakarta, Lampung, South Sulawesi, South Sumatera, and Riau.

The second parameter is the current adoption rate. The application of rooftop PV that PLN has recorded is currently concentrated in Jakarta (755 users), West Java (673 users), Banten (632 users), East Java (199 users) and Bali (96 users) (Haryadi et al., 2021). Therefore, this study concludes that Jakarta, West Java and Banten have a high adoption of rooftop PV. Meanwhile, East Java and Bali are set with a moderate adoption level (IESR, 2019).

In conclusion, based on the parameters of market potential and current adoption rate, this thesis focuses on the development of rooftop PV in cities with the high market potential and high adoption rate. These cities are Jakarta, West Java and Banten. Table 5 presents all evaluations of geographical boundaries for this thesis

Table 5. Evaluation of technical potential, adoption level and willingness in adopting rooftop PV (●: high; ◖: moderate; ○: low)

Province \ Parameters	Market Potential	Current Adoption level
East Java	●	◖
West Java	●	●
Central Java	●	○
North Sumatera	●	○
Banten	●	●
Jakarta	●	●
Lampung	●	○
South Sulawesi	●	○
South Sumatera	●	○
Riau	●	○

3.4 Research flow

This section describes the research flow designed by the researcher to answer the research question explained previously in the chapter 1. First, this study started by identifying the research problem. As explained in chapter 1, the research problem is related to sustainability goals in Indonesia, namely Indonesia's goal to reach 25% renewable energy in energy mix by 2025, reduce 29% of its emission by 2030 and become zero-emission country by 2060. Second, this study is continued by formulating the problem statement and research objective. Chapter 1 explains that the problem statement of this research are the slow growth of rooftop PV, a complex process of sustainability transition to rooftop PV and the important role of business model. Thus, this study was formulated to investigate the transition and niche development process of rooftop PV and, moreover, examined the existing rooftop PV business model in Indonesia. Subsequently, a literature review on the existing publications on energy transition, SNM framework in developing countries, business model was conducted. Based on the literature review, one main research question and four sub-research questions were formulated. To answer the research question, the research methodology was developed and explained in this chapter. Finally, data collection, data analysis, drawing conclusions and recommendations was conducted. The flow of this study is presented in the following flow diagram (figure 7).

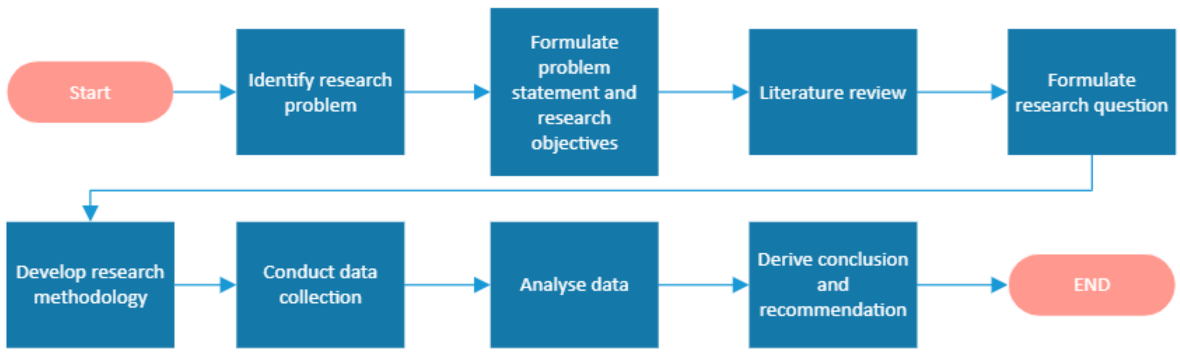

Figure 7. Research Flow Diagram

Furthermore, the following explanation is given as a flow to answer each sub-research question that has been formulated previously.

1. What are the main actors and factors influence rooftop PVdevelopment in Indonesia?
   Energy transition to rooftop PV in Indonesia is considered a complex process as it involves multiple stakeholders, including the government, producers, manufacturers, finance institutions, associations and users. To have an inclusive analysis of the rooftop PV development, identification of the key stakeholders involved and the social dynamics (interconnection) between those actors are conducted. The current sub-research question aim to shed light on the influence of stakeholders involved in policy-making, business ecosystem, technology development and social impact.
   First, identification of the main actors began by studying the technology chain of rooftop PV in general. In this case, technology map of rooftop PV was analysed and used to investigate the value chain. Second, the stakeholder analysis is conducted by identifying involved actors, represented by an actor map that explains the roles of each stakeholders, resources (power), interests, and social dynamics between actors. Furthermore, the influence of each actors and their interconnections on the niche development of rooftop PV is explained using MLP framework. In this framework, the social dynamics between each actors is examined in three levels (socio-technical landscape, regime, and niche innovation).
2. What are the main barriers and opportunities to rooftop PV development in Indonesia?
   The availability of solar energy resources in Indonesia is considerably large, but its potential has only been utilized by 0.04% (MEMR, 2017b). This sub-research question aims to explore the current barriers and opportunities in the development of rooftop PV. Factors such as environmental issues, technology, financial support, implementation process, and influence of dominant actors are discussed.
3. What type of business models currently applied, and how has it influenced the rooftop PV niche development in Indonesia?
   The development of rooftop PV involves a wide range of business-related stakeholders, such as a dominant power-grid company, multiple rooftop PV providers and technology manufacturers. The

third sub-research question aims to explore the business activities by these actors that contribute to the niche development of rooftop PV. These business activities are presented in business model canvas developed by Osterwalder et al., (2005)

4. How can the niche market of rooftop PV in Indonesia be accelerated?
   At the end of the study, recommendations to accelerate the diffusion of rooftop PV in Indonesia are given. Based on the results of the previous three sub-research questions regarding stakeholder analysis and social dynamics, analysis of barriers and opportunities, and exploration of business models, the conclusion and recommendation were made.

3.5 Data collection, treatment and analysis

Two data collection methods used in this thesis project were desk research method and interview method. This section briefly describes the two data collection methods. Moreover, the description of the flow of data collection, interview protocol data analysis, and data management plan are also provided.

3.5.1. Desk research

A desk research was conducted to collect the relevant data and analyse it. Similar to the literature review described earlier, desk researchuse a variety of literature, including journal publications, papers, government reports, corporate policies, laws and regulations. This literature were searched through academic research engines, such as Scopus, Google Scholar, ScienceDirect, TU Delft repository, and public research engines, such as Google. In addition, due to the limited sources of academic literature, secondary data was also collected from non-academic literature such as online newspaper (Jakarta Post, Kompas, Kumparan Bisnis, Media Indonesia and KabarTangsel), government websites (ministries and house of representative), company websites (rooftop PV provider, bank, and venture capital) and global organization (IRENA).

3.5.2. Semi-structured interview

Semi-structured interviews weere conducted as a data collection method to gather the primary data and information that cannot be obtained through a desk research. A semi-structured interview is one type of interview method in which the interviewer will be allowed to ask additional questions beyond the pre-determined questions (Edwards & Holland, 2013). Accordingly, semi-structured interviews will enable researcher to find an in-depth and rich data (Mann, 2011). The aim of the semi-structured interviews was to collect information and insights in the case study on the development of niche innovation rooftop PV.

Due to the limitation of literature explaining rooftop PV in Indonesia, interviews with various key stakeholders is necessary to answer sub-research questions. Moreover, to collect a broad perspective, this study involved set of respondents from multiple backgrounds. Table 6 shows the interviewees' list, including the central government, provincial government, state-owned companies, private companies, technology producer (PV module and inverter), research organisations, manufacturer association and user association. The principal investigator will initially contact respondents through Emails and LinkedIn..

In terms of cconducting the interview, considering the COVID-19 pandemic and the geographical differences between the interviewer and respondents, the interview was conducted online. Online interviews, categorised as telephone interviews, allow the investigator to contact geographically dispersed subjects (Sekaran & Bougie, 2007). Several platforms such as Zoom meeting and Microsoft Teams were used during the interview.

Table 6. List of interviewees

Interviewee	Actor Type	Job description
#1	Developer	Renewable energy professional
#2	EPC	Business developer
#3	Researcher (University)	Researcher director
#4	State-owned energy company	Researcher and technical advisor
#5	Supplier	Business developer
#6	Provincial government	Electrical inspector and Renewable energy developer
#7	NGOs	Researcher
#8	Developer	*Project finance manager*
#9	Financial institutions	*Sustainable financer*
#10	Utility company	Business strategy developer
#11	Utility company	Business strategy developer
#12	MEMR	Deputy director
#13	MEMR	Staff of deputy director
#14	Manufacturer association	Member and director operation
#15	Users association	Founder

The interview questions are constructed based on the theoretical framework (SNM, MLP and business models) described earlier in the chapter 2. These three key theoretical concepts were operationalized (described in the section 3.1) and inserted as the questions. The questions relate to theory such as niche shielding or niche protection (active and passive), nurturing (expectation, social networks, and learning process), empowerment, and also social dynamic in multi-level (landscape, regime and related). These questions were asked to all respondents. Meanwhile, the questions related to the business model were asked to stakeholders from the business industry, such as PV providers, technology manufacturers and distribution grid company (PT. PLN). The question are listed in the Appendix A.

3.5.3. Data collection flow

Data collection will be conducted as the following step (figure 8):

1. Determining the information require. The required information was acquired from the desk research and secondary data collection from actors involved in the rooftop PV development.
2. Preparing formal interview request letters will be the second step in the procedure. The formal is fully contained with the TU Delft ethics regulation.

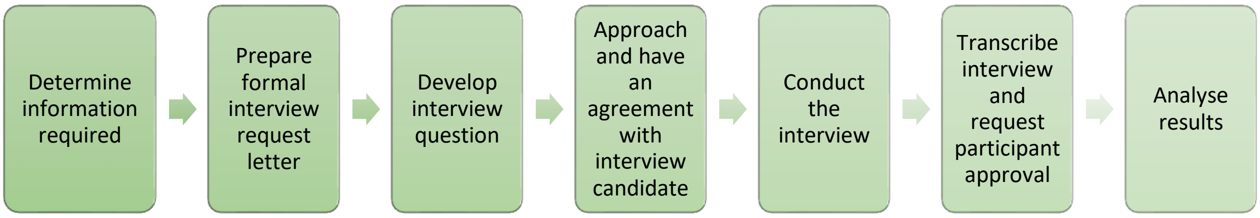

Figure 8. Data collection procedure

3. To ensure the clarity and alignment of the question, the list of questions was pre-determined
4. Approach and have an agreement with the interview candidate. Before approaching the interview candidates, the interviews process was organised according to the Human Research Ethics Committee (HREC) rules at TU Delft. To ensure this, a checklist sheet for human research has been fulfilled. The checklist sheet provided in appendix B submitted to the HREC TU Delft. Subsequently, the researcher arranged the interview by setting the schedule based on the respondent's availability.
5. Before conducting the interviews, the respondent was asked whether the meeting can be recorded. Next, the prepared question was asked.
6. The insight from the interview was gathered and transcribed. And before the conclusions of the discussion were processed, approval from the participant will be requested.
7. Analyse results

3.5.4. Interview protocol

The following interview protocol is developed to guide the interview process and ensure that the interview follows the ethics regulations.

1. The interviewer will provide a list of questions to the respondent in advance to ensure the continuity of the interview.
2. Before starting the interview, the interviewer will explain the consent form provided in Appendix B.
3. The respondent will be asked permission to record the interview and quote the statement for the analyses.
4. At the beginning of the interview, the interviewer will explain the background and purpose of the research.

5. Subsequently, the interview will ask a question, and the respondent will respond to the question.
6. The interview will take approximately 45-60 minutes.

3.5.5. Data analysis

Since this study uses multiple data collection methods triangulation (i.e. interview and desk research), multiple resources (i.e. papers, journal, website, and newspapers), various stakeholders (i.e. governments, companies, and organisations) and multiple theoretical frameworks (i.e. SNM, MLP and business model framework), data triangulation will be necessary to validate the result. Triangulation is one of the data validation techniques in qualitative research where the researcher uses several methods for verifying the findings (Sekaran & Bougie, 2007). Moreover, to analyse the data, the primary data will be coded and analysed by adopting a qualitative data analysis software, namely ATLAS. ti.

3.5.6. Data management plan

A data management plan describes how the data will be collected, used, and stored during the study. The management plan will be developed using the TU Delft template in DPMonline. In general, the data management plan used in this thesis is shown in Table 7. The following table presents the data management plan that the researcher will use during the interview.

Table 7. Data Management Plan

Type of data	File Format	How will information be collected?	Purpose	Storage location
Email address for digital communication	e-mail address	Outlook	Communication	Outlook
Video recording of the interview	Mp4 file	Online platform recording (i.e. Zoom recording Teams recording)	Data collection, transcript of the interview	One Drive
Transcript of interview	Docs	Transcription of the MP4 file	Archive	One Drive
Report, Paper summary	Docs	Literature review	Archive	One Drive

3.6 Research validity and reliability

According to Yin (2014), several procedures should be taken into account to ensure the validity and reliability of a case study. This section contains several measures employed to ensure external validity, internal validity, construct validity and reliability of this study. First, the use of multiple case studies, which includes a broad cross-section (different roles) of the interviewees, helps to investigate rooftop PV development in different contexts, which improves the generalizability of the findings (Brereton et al., 2008). This measure is applied to ensure the external validity of this study. Secondly, the use of case study protocol (case study design, case selection, research flow, data collection, treatment, analysis and procedure for validity) and the application of the analytical framework (described in chapter 3.1) support the consistency and repeatability of a case study. These measures improve the case study's external validity and reliability (Brereton et al., 2008; Yin, 2014). Thirdly, this study uses multiple sources of evidence (from interviews and desk research) to ensure construct validity of the case study (Yin, 2014). Interviews with stakeholders from different roles and desk research on numerous academic resources (i.e., papers or articles) and non-academic resources (i.e., documents, reports and archives) help sustain a case study's construct validity.

Another concern for a case study is internal validity, such as the selection bias in the interviewee selection process. This bias in the subject selection might affect the cause-and-effect relationships between two elements and lead to assessment inaccuracy (Sekaran & Bougie, 2016). The current study should consider this internal validity when explaining the influence of business models on rooftop PV development. The pattern matching strategy described by Yin (2014) is employed to minimise the bias issue. Pattern matching empirically compares an observed relationship pattern with the theoretical pattern. In this study, the influence of business models on rooftop PV development is analysed by comparing the data received from interviews with the theoretical framework from Bidmon & Knab (2018), which explains the three roles of business models in the transition process..

CHAPTER 4 – ROOFTOP PV INDONESIA

This chapter aims to answer the first sub-research question, “What are the main actors and factors influencing rooftop PV development in Indonesia?”. To answer this question, several topics will be explained. First, the history of rooftop PV development will be briefly presented. Secondly, the rooftop PV technology will be described, including the working principle, the types and the comparison between types. The technology map will be presented in the first section. Third, stakeholders that have been involved in the rooftop niche development are analysed. List of stakeholders, descriptions of each stakeholder, and a stakeholder map are presented. Lastly, the factors influencing niche development are identified and explained. All of these topics are described and analysed using desk research and interview.

4.1 The history of rooftop PV development in Indonesia

PV systems in Indonesia have been developed since the 1970s by a pilot project for a radio-controlled railway system in Java in 1977. From 1977 until 1989, the development of PV concentrated on research and pilot project. During this period, another three projects were developed by Indonesia's Agency for the Assessment and Applications of Technology (BPPT) (Outhred & Retnanestri, 2015). Rooftop PV was first applied in Indonesia in a solar home system demonstration project at Sukatani village, West Java, started in 1988. The solar home system was installed in 80 houses, an office of the head of the village, three mosques and a Muslim school. Subsequently, the rooftop PV was used in solar homes system in Lebak, West Java. Until February 1993, solar home systems were in 500 locations in eleven villages (de Quay, 1994). Figure 9 shows the application of rooftop PV in the solar home system demonstration project in Sukatani and Lebak.

Figure 9 Rooftop PV application in the solar home system demonstration project in Sukatani and Lebak (de Quay, 1994, p. 48)

From 1990 – to 1997, the development of PVS began to launch demonstration and semi-commercial projects. Various projects were introduced by government agencies, private companies and state-owned companies, including Telkom and Pertamina. Since the Sukatani project, the President of Indonesia was enthusiastic about the solar home system technology that he started the Banpres project in 1990. The Banpres project provided interest-free credit for 3000 solar home systems (Lysen, 1994). The diffusion of rooftop PV continues in a project directed by the Ministry of Health. The project aimed to install 7500 solar panels for 270 health clinics all over Indonesia, especially in rural health centres. Besides the installation in the clinics, several PV systems were also installed on the rooftop of the doctor's and nurses' houses (de Quay, 1994). In 1997, the government of Indonesia launched a programme to install one million solar PV using solar home system programs (50 MWp) nationwide by 2005. Figure 10 presents the project implementation of one million rooftop PV. Subsequently, in 1997, the World Bank initiated Solar Home System (SHS) project in Indonesia. The project aimed to develop 200,000 sales units of PV. However, the PV system's development was hampered by the Asian Financial Crisis in 1997 (Outhred & Retnanestri, 2015).

Figure 10 One million solar PV projects in rural development (SELF, 2022)

The development of PV in Indonesia continues after 1999. Especially in 2006, Government launched the National Energy Policy to aim at 17% of the energy mix generated from RE by 2025. Following the policy, state-owned electricity company PLN announced various PV projects, including 'PV for Island' in 2011-2012 and 'PV for 1000 islands' in 2013-2016. Moreover, to boost PV deployment, the Government introduced a feed-in tariffs policy that offers 30 US cents/kWh (Outhred & Retnanestri, 2015). In 2014, the target of RE adoption was increased to 25%. To achieve this target, in 2017, MEMR, together with the Ministry of Industry, other government stakeholders, associations, and universities, introduced the One Million Rooftop Solar Initiative (GNSSA) to promote solar energy, particularly rooftop PV, development and deployment in Indonesia.

Furthermore, in 2018, the government introduced a new MEMR Regulation No. 49/2018 on rooftop solar PV. This regulation provided a legal assurance and technical regulation for users regarding rooftop solar PV installation procedures and transactions with PLN. Moreover, in this regulation, the feed-in tariffs were offered of 1:0.65 ratio. This scheme allows customers to operate their rooftop PV parallel to the PLN grid (Hamdi, 2019). In 2021, the feed-in tariffs were revised in the new MEMR Regulation No. from a 1:0.65 ratio to 1:1.

4.2 Description of Rooftop PV Technology

This section is a preliminary attempt to explain rooftop PV technology to provide readers with a basic understanding. This description will assist readers in following the entire discussion in this report. First, the readers will be given an explanation of the working principle of rooftop PV. Consequently, two types of rooftop PV (stand-alone rooftop PV system and grid-connected rooftop PV system) will be explained. Finally, the description of all components of rooftop PV is described briefly, and the technology map is provided.

5.1.1. Working principle and classification of rooftop PV

The term 'Rooftop PV' has been used to refer to a type of roof-mounted PV system, such as household rooftops or industrial rooftops. In general terms, a photovoltaic (PV) cell, also commonly called a solar cell, is defined as a device used to convert light energy into electrical energy through a process called the photovoltaic effect. The process begins when the light reaches the solar cells. Some light will enter the cells and be absorbed by the PV material, including materials like silicon. The energy from the light will trigger the electrons in the cell to move freely. The moving electrons, defined as electrical currents, generate electrical energy (Mohanta et al., 2015b). To increase the rooftop PV capacity, the number of installed PVs needs to be improved. This number of PV is connected in parallel or series. Furthermore, the electrical energy generated in the PV cells is usually transmitted to the grid or stored in the local battery.

Based on the installation system, rooftop PV can be categorised into two types, namely stand-alone rooftop PV and grid-connected rooftop PV (Singh, 2018). The description of each system is provided as follows:

A. Stand-alone rooftop PV

Stand-alone rooftop PV, also called off-grid rooftop PV, is an isolated system that generates electricity without connecting to the current utility grid. In this system, the electricity generated in the PV is consumed in the same household without transferring to another place (Kunaifi et al., 2020). In this system, the electricity is stored in the battery. The main components are solar modules, mounting system, inverter, charge controller and battery (Mohanta et al., 2015b).

B. Grid-connected rooftop PV

Grid-connected rooftop PV, commonly called on-grid rooftop PV, is a rooftop PV system connected to the current utility grid. Grid-connected rooftop PV can be distinguished into two types, namely grid-tied systems and hybrid systems. A grid-tied system is defined as a system that transfers electricity to the grid system without a storage system. The main components of this system are solar modules, inverters, and smart meters. In contrast to a grid-tied system, a hybrid system is a system equipped with a storage system that allows owners to store and provide power locally (Kunaifi et al., 2020). In this sense, the main of this system are solar modules, inverters, smart-meter, battery, and charge controller.

5.1.2. Comparison of all types of rooftop PV

According to Mohanta et al. (2015), Kunaifi et al. (2020) and Singh (2018), several advantages and disadvantages of each system are summarised in the following table.

Table 8. Comparison of all types of rooftop PV

	Stand-alone	Grid-connected (Grid-tied system)	Grid-connected (Hybrid system)
Advantages	• Suitable for implementation in a remote place • No power outages and bills • Clean, renewable energy sources	• Suitable for implementation in a rural area • Have a reserve electricity resource from the utility grid • Feed-in-tariff applicable	• Suitable for implementation in a rural area • Able to provide energy to the grid and receive energy as a backup from the grid power • Feed-in tariff applicable
Disadvantages	• Additional equipment is battery and charge system • Unable to provide electricity in the long term due to limited capacity of the battery • Battery unable to store power in the long-term	• Additional equipment is a smart meter • Not fully renewable resources due to supply from the grid	• Additional equipment is a smart meter, battery and charge system • Not fully renewable resources

5.1.3. Technology map

To understand the niche development of rooftop PV, it is necessary to understand what technology is involved in the system. In this section, some of the technological components influencing the diffusion of rooftop PV are investigated. These elements, including key technologies, surrounding technologies, distribution networks, and infrastructure, are explained. As shown in figure 11, the technology map is used to indicate the system's structure. A detailed description of each component will be givens in the following section.

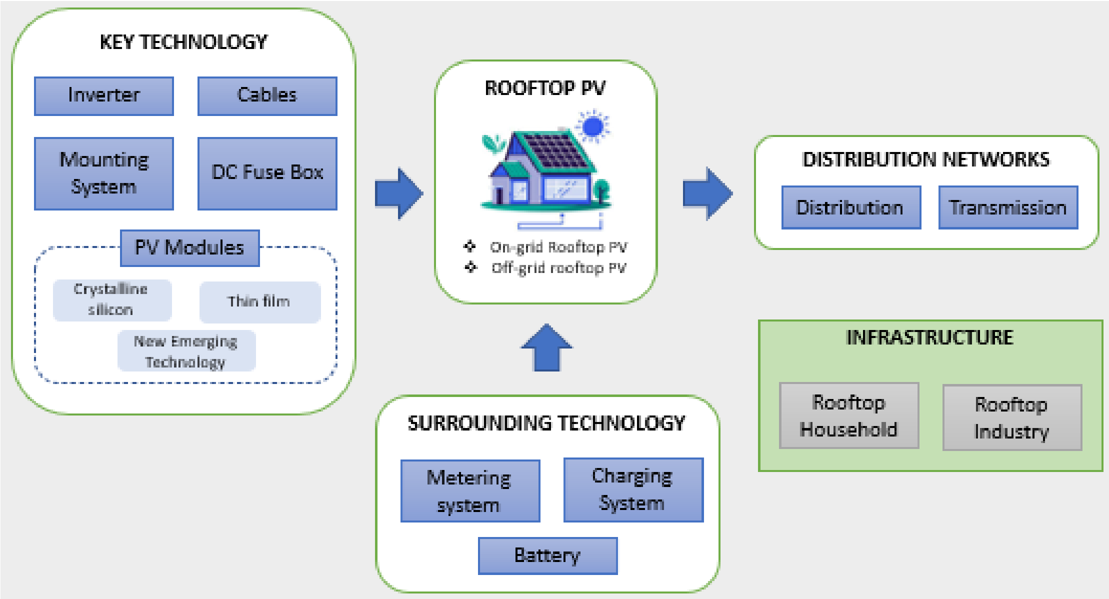

Figure 11. Technology Map of Rooftop PV

A. Key Technological Components

To generate electrical energy, rooftop PV consists of several main technological components. As shown in figure 11, elements such as PV module, mounting system, cable, protection system and inverter are essential to structure rooftop PV system. These components are explained in detail in the following section.

➢ PV module

The solar PV module is a fundamental component of the rooftop PV system, converting light into electrical energy. As described previously, PV modules are defined as a set of several PV cells connected in series or parallels. The modules are combined in series to generate a higher voltage; meanwhile, the modules are connected in parallel to produce a higher current (Albadi et al., 2014). According to Mohanta et al. (2015), PV modules can be categorised into crystalline silicon (C-Si), thin-film technology, and other emerging technologies.

Crystalline silicon (C-Si) module, also known as the first generation of solar cells, is the most commonly used PV cell produced from silicon crystal. The crystalline module is also known as the most efficient technology compared to thin-film technology and concentrator PV organic. In terms of crystallisation level, the crystalline module can be categorised into monocrystalline and polycrystalline (Mohanta et al., 2015b). Monocrystalline modules are made from a large silicon crystal; however, polycrystalline modules are made from silicon crystal grains. In terms of efficiency, monocrystalline modules are the most efficient type, with an efficiency ratio of 18%. On the contrary, polycrystalline modules have a lower efficiency ratio of 13% to 15% than monocrystalline (Albadi et al., 2014).

Thin-film technology is a PV module that consists of very thin photovoltaic materials placed on glass or metal superstrates (Mohanty et al., 2016). Since it uses very thin materials, the thin-film modules are more suitable for applications on windows, cars, and buildings. However, compared to crystalline silicon modules, thin-film technology is less efficient but at a lower cost (Mohanta et al., 2015b).

New emerging technologies. Several technologies, including concentrator PV, have been mentioned by Mohanta et al. (2015) as promising novel PV cells technology. This technology is not commercially proven. Compared to another module, concentrator PV is less efficient but with a meagre cost. Other novel technologies are dye-sensitized cells, organic PV, tandem cells, and thermos-PV (Mohanty et al., 2016).

- **Mounting system**

The mounting system consists of several elements such as plates, nuts, and bolts, which are used to mount the PV modules on the roof. To avoid corrosion, materials like an aluminium plate and stainless-steel nuts and bold are recommended to use. Moreover, it is also recommended to place the panels at a perpendicular angle to the noon-day sun, such as at an angle that face the equator (Mohanty et al., 2016).

- **Cable**

Cables or conductors are insulated wires used to transmit the electricity from one electrical component, such as a PV module, to another element, including a battery. In designing a PV system, the length and size of the cable need to be considered due to the voltage drop during operation. If the cable size is too small, the voltage drops increase and influences the system, especially triggering a decrease in battery voltage (Mohanty et al., 2016).

- **Inverters**

In general terms, an inverter is defined as a technology that can convert one form of electrical energy, which is a direct current (DC) form, into an alternating current (AC) form. In the case of rooftop PV, the inverter is used to convert electrical energy stored in the battery (DC form) to the electrical form of the utility grid (AC form). Therefore, this device is essential for a rooftop PV system to allow the system to connect to the utility grid or be used by electrical appliances (Albadi et al., 2014).

- **Protection system (Fuse Box)**

A protection system, such as a fuse box, is an electrical safety device used to protect all components of a rooftop PV system from an electrical circuit issue, including overcurrent. Several fuses installed in rooftop PV systems are battery fuse disconnect, inverter fuse disconnect and PV fuse disconnect (Mohanty et al., 2016).

B. Surrounding Technology

Apart from the previously described key technological components, rooftop PV is also supported by several other technologies around the system. These surrounding technologies are smart meters, batteries and charging systems. These technologies are installed based on the type of the system, such as whether the system is a stand-alone, grid-connected grid-tied, or grid-connected hybrid system. The description of each component is provided in the following section.

- **Metering system**

A metering system is used to count the amount of energy produced by the PV system and the amount of power supplied by the energy grid. The metering system is essential for grid-connected systems. Based on the working principle, the metering system can be categorised into two types: single-metre and two-metres. A single-metre system records the energy produced when the power is generated and records the amount of energy supplied when the power is received from the grid. In contrast, two-metre metering systems consist of two separate metres. One metre is used to record the amount of energy generated, and the other metres is used to record the power supplied to the grid (Albadi et al., 2014).

- **Battery**

Batteries are another surrounding technology of rooftop PV, which are used to store the electric energy generated in PV cells. Due to the intermittency of solar power that leads to the unstable and unpredictable variation of PV modules' output, batteries are essential for stand-alone PV systems and hybrid systems to make the energy available constantly. In general, there are two types of batteries in PV system applications: lead-acid batteries and deep cycle batteries. Due to the good availability, cost-effectiveness and capability to generate high currents, lead-acid type batteries are commonly used (Mohanty et al., 2016).

- **Charging system**

The charging system controller is a device used to regulate the solar panel's output to the battery. This device is designed to limit the charge rate and discharge rate of the electric current. The device protects the batteries from electrical problems, such as overcharging, overload and overvoltage (Albadi et al., 2014).

C. Distribution Network

The term distribution network in this section refers to the network where the electrical energy generated in the PV module will be distributed. Based on two classifications of rooftop PV, two distribution networks have been identified. The two distribution networks are explained as follows.

- **Grid distribution**

Grid distribution is referred to current utility grid. The term applies only to grid-connected rooftop PV, where the electricity generated in the PV module is transmitted to the existing grid (Mohanta et al., 2015b).

- **Electrical appliances**

Electrical appliances refer to the instruments in homes, industries, or companies that use PV modules' energy. The electrical appliances term is applied to the stand-alone rooftop PV type. In the case of households, the term electrical appliances refer to household equipment. In the case of industry or company, the term electrical appliances refer to the devices inside the industry or company (Mohanta et al., 2015b).

D. Infrastructure

As previously mentioned, the infrastructure that affects the diffusion of rooftop PV is the availability of the roof infrastructure. Roof infrastructure can be classified into roofs in public houses and roofs in the industry.

4.3 Stakeholder Analysis

To answer the first sub-research question regarding which actors influence the development of rooftop PV in Indonesia, this section presents a stakeholder analysis of the actors involved in Indonesia's rooftop PV business ecosystem. This stakeholder analysis considers several perspectives mentioned in Yudha & Tjahjono (2019), namely Political, Economic, Social, Technological, Legal and Environment (PESTLE), as a foundation of the analytical method. A description of each perspective is provided in table 9. Based on this perspective, this study categorises stakeholders into five different groups: (1) Stakeholders related to politics and legal; (2) Stakeholders related to the economy; (3) Stakeholders related to the social and environmental impact; (4) Stakeholders related to technology; and (5) Value chain related stakeholders. Figure 12 summarises stakeholder map of all the actors in Indonesia's rooftop PV development. A detailed description of each group and the relations between stakeholders are given in the following section.

Table 9. Description of PESTLE analysis (adopted from Yudha & Tjahjono (2019))

Factor	Description
Political	Examine from the political perspective, including the influence of government power and the process of making regulations
Economic	Looks at the financial provider and impacts of rooftop PV development on the economy - for instance, the economic impact on the organisation, or industry
Social	Examine the social impact of rooftop PV on cultural trends, demographics, and population

Factor	Description
Technological	Related to the technology requirement, including research and development of the technology and supply chain
Legal	Related to the regulation and laws such as feed-in-tariffs regulation
Environmental	Investigate the vital factors impacted by the environmental issue, geographical boundary, etc.

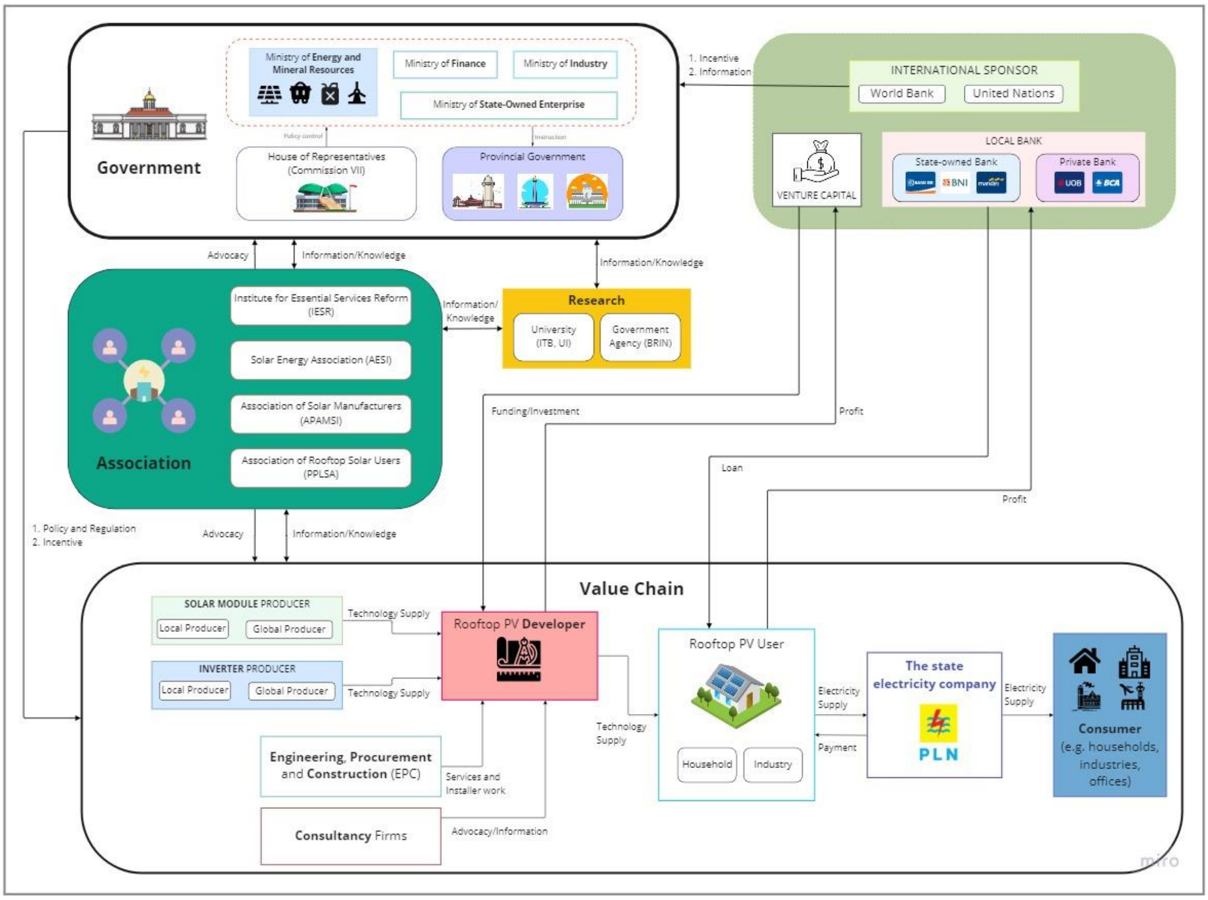

Figure 12. Stakeholder Map

4.3.1. Stakeholders related to political and legal

This stakeholder group consists of stakeholders who influence the political sphere, such as law and regulation decision making. Three main actors have been identified as involved in the development of rooftop PV in Indonesia: (1) the Ministry; (2) the Provincial government; and (3) the House of Representatives. The explanation of this stakeholder is provided as follows.

a. Ministries

Four ministries are identified to have influenced the rooftop PV development in Indonesia. First, the Ministry of Energy and Mineral Resources (MEMR) is a crucial stakeholder responsible for managing all energy sectors, including making policies and laws for rooftop PV (Yudha & Tjahjono, 2019). The MEMR primarily focuses on ensuring energy supply meets the ever-increasing demand due to the growing population and economic level. In addition, the MEMR is currently focusing on designing an energy plan to achieve Indonesia's sustainability goals: 29% emission reduction in 2025 and zero emission in 2060 (MEMR, 2022a). The organisation structure of the MEMR consists of several divisions. Two divisions are essential in rooftop PV development. The Director-General of Renewable Energy and Energy Conservation is one division that supervises all activities, policies, norms, standards, and criteria regarding renewable energy and energy conservation. Another division is the Director-General of Electricity which manages the electricity sector in Indonesia in collaboration with the state-owned electricity company, PT. PLN (Yudha & Tjahjono, 2019). The Ministry of Finance is another essential stakeholder that manages, formulates, and implements government budgeting and spending policies, including a financial incentive for renewable energy such as rooftop PV (Yudha & Tjahjono, 2019). The primary concern of the Ministry of Finance is to ensure the effective, productive, and efficient use of government finances (Ministry of Finance of the Republic of Indonesia, 2022). Another ministry influencing the development of rooftop PV is the Ministry of Industry which is responsible for improving the competitiveness of local industries and creating policies to support the local producer in developing rooftop PV (Ministry of Industry of Republic Indonesia, 2021). The Ministry of Industry includes the solar PV industry in the National Industrial Development Master Plan (RIPIN) 2016-2035, which describes PV's medium and long-term development plan in Indonesia (MEMR, 2017a). Finally, the Ministry of State-owned Enterprise has responsible for managing 60-70 companies, including the dominant state-owned electricity company PT.PLN. The primary interest of this ministry is to increase the economic and social value of Indonesia (Ministry of State-owned Enterprise of Republic of Indonesia, 2022). To support the diffusion of rooftop PV, the Ministry of State-owned Enterprise has instructed all 70 state-owned companies to install rooftop PV in offices, factories, and employee houses (Agustinus, 2021).

b. Provincial government

Another political and legal-related stakeholder is the provincial government, responsible for managing all activities in a specific area, including actions to support the development of rooftop PV. For instance, the Government of Jakarta, aiming to become a net-zero carbon city by 2030, aims to reach 900MW of rooftop PV by 2030 (ESCAP, 2021). To achieve this goal, the Jakarta Government plans to install rooftop PV at all government-owned buildings, including offices, schools, sports centres and medical facilities (Prakoso, 2019). Another example is the Government of Banten, which conducts seminars and workshops to stimulate rooftop PV dissemination in their area (PWHTHS, 2020). Finally, the Government of West Java, a vast industrial space, aims to reach a 20.1% energy mix from renewable energy and

918MW of solar power by 2025. The Government of West Java encourages the industry to use rooftop PV in its building and factory (Media Indonesia, 2021).

c. House of representative

The last stakeholder related to politics and legal is the House of Representatives. In general, the duties of the House of Representatives are to follow up and control the policies taken by the government. In this case, the House of Representatives can approve or reject the government regulation. Moreover, as the public representative, the primary concerns are to ensure all the policies implemented by the government are performed in the public's interest and mandated by the 1945 Constitution and the laws. (The House of Representatives of the Republic of Indonesia, 2022).

The Indonesian House of Representatives consists of eleven commissions. Commission VII is responsible for following up on all the energy, industry, research, and innovation policies. For instance, in 2020, Commission VII conducted a public hearing meeting (RDPU) with several renewable energy-related associations, including the Indonesian Renewable Energy Society (METI) and Indonesian Electricity Society (MKI), to discuss National Draft Regulation for Renewable Energy (RUU EBT). In this meeting, Commission VII gathers public opinions regarding government policy on renewable energy (IESR, 2020). Another example is the control by the House of Representatives on the policy taken by MEMR regarding the 100% feed-in tariff of rooftop PV. A member of Commission VII, Mulyanto, in a press conference, said the regulation from the MEMR regarding the feed-in tariff of rooftop PV needs to be revised because it has the potential to reduce the profit of state-owned electricity companies PT.PLN (Commision VII, 2021). The job function described and examples show that the House of Representatives influences the development of rooftop PV, which needs to be discussed in the MLP analysis.

4.3.2. Stakeholders related to economy

The second stakeholder category consists of actors who influence rooftop PV development by providing financial support. Three groups of actors are identified to influence rooftop PV development: (1) Local investors, (2) International investors, and (3) Venture capital.

a. Local investor

This report defines the local investor as stakeholders from the local Indonesian area who has the financial resources to provide financial support to the rooftop PV ecosystem. In addition to the Ministry of Finance, which delivers tons of incentives, several other local actors, including state-owned banks and local private banks, offer several programs to boost rooftop PV adoption (Karyza, 2021). For instance, the three biggest state-owned banks in Indonesia, such as Bank Rakyat Indonesia (BRI), Bank National Indonesia (BNI), and Bank Mandiri, offer loan programs for industrial users and household users (Setiawan, 2021). Through the 'U-Solar Programme in Indonesia', the UOB Bank, as a local private bank, promotes the solar panel industry and the use of rooftop PV in industrial areas and households (BANK UOB, 2019). These two examples show that local investors' participation through the loan programme business model is necessary to encourage users to adopt solar panels, which aligns with the SNM framework and nurtures the rooftop PV industry.

b. International investor

International investors, such as World Bank, are stakeholders from outside Indonesia who provide funds to support rooftop PV development. World Bank aims to reduce poverty worldwide by implementing sustainable solution programs, namely Energy Sector Management Assistance Program (ESMAP) (World Bank, 2022b). ESMAP provides support, including funding and publications related to rooftop PV (ESMAP, 2022).

United Nations is another international investor supporting renewable energy development, such as rooftop PV in Indonesia. United Nations' lead agency on international development, United Nations Development Program (UNDP), collaborates with MEMR to organise a new project called Market Transformation for Renewable Energy and Energy Efficiency (MTRE3), which designs a scheme to increase the adoption of rooftop PV. In this MTRE3 program, the allocation fund called Sustainable Energy Fund (SEF) is provided and offered directly to the new users (United Nations Development Program, 2022).

c. Venture capital

Venture capital is another stakeholder who financially invests in early-stage or growth start-ups in a wide range of industries, including rooftop PV. For instance, in series A investment funding, two venture capitalists, East Ventures and PT Saratoga Investama Sedaya, invested USD 21.5 million in one renewable energy start-up that focuses on rooftop PV, PT Xurya Daya Indonesia. Besides aiming for the profitability of investment, this venture capital also seeks to support the social impact and sustainability of the technology (East Ventures, 2022).

4.3.3. Stakeholders related to the social and environmental matters

This stakeholder group focuses on the social and environmental impacts of rooftop PV in Indonesia. Most of the stakeholders identified are associations: (1) Association of solar manufacturers (APAMSI), (2) Association of rooftop solar users (PPLSA), (3) solar energy association, and (4) Institute for essential services reform (IESR). The description of each stakeholder is presented as follows.

a. Association of solar manufacturers (APAMSI)

Indonesia association of solar manufacturers (APAMSI) consist of various companies of PV modules developer in Indonesia that envisions itself as a strategic partner with the government and stakeholders to advocate for the development of solar PV. In 2021, 11 (eleven) companies have joined APAMSI, namely PT Adyawinsa Electrical & Power, PT Azet Surya Lestari, PT Len Industri, PT Surya Utama Putra, PT Swadaya Prima Utama, PT Wijaya Karya Industri & Energi, PT Sankeindo, PT Deltamas Solusindo, PT Indodaya Citra Lestari, PT Jembo

Energindo, and PT Sky Energi Indonesia. The total production capacity of APAMSI members is 500 MWp. APAMSI aims to create solar PV more efficient, affordable and accessible for everyone (APAMSI, 2021).

The role of APAMSI in solar PV development can be seen in 2014 when feed-in-tariff (FiT) was implemented for a short period from 2013-to 2014. The FiT policy was cancelled due to a legal protest action by APAMSI protesting the local production requirement policy. The policy stated that 40% of the PV's requirement must come from local production. However, APAMSI wanted to ensure all the solar PV projects used local-produced PV. The legal challenge was accepted, and the regulation was revised in 2015 (Hamdi & IEEFA, 2019). This example of APAMSI action shows its influence on solar PV development through advocation to the government.

b. Association of rooftop solar users (PPLSA)

Indonesia Association of rooftop solar users (PPLSA) is a non-profit and open member-based organisation consisting of rooftop PV users, suppliers, researchers and beneficiaries. PPLSA aims to support the diffusion of renewable energy by increasing the accessibility of rooftop PV for everyone. To implement that, PPLSA provides advocation for rooftop PV users, including household or commercial users. Furthermore, PPLSA is also a communication forum for its member. For instance, on one social media, namely Facebook, PPLSA allows users to share their experiences, ask questions, or even promote their business related to rooftop PV (PPLSA, 2016).

c. Solar energy association (AESI)

The third stakeholder in this group is the solar energy association. The Indonesian solar energy association or AESI is another non-profit organisation usually defined as a communication forum where stakeholders such as policymakers, business actors, experts, and users of PV collaborate. According to AESI (2022), AESI has three main activities to support PV development. The first activity is policy advocacy, where AESI arrange focus group discussion with several stakeholders and intensively discuss policy with the policymaker such as MEMR. The second activity is related to the business development and financing of solar energy. In this activity, AESI collaborates with several financial institutions, such as local and international institutions, to accelerate the adoption of all-scale solar PV development projects. In addition, AESI also analyses several projects to identify projects that have the potential to be developed. The last activity is entrepreneurship and human resources development. One of AESI's main priorities is the 'Solarpreneur' initiative, which focuses on increasing the number of business actors in the engineering, procuring, and construction solar energy. Currently, AESI has 84 individual members (e.g. academia, practitioner, policymaker) and 50 organisations (e.g. solar developers, solar EPC, state-owned companies, and non-government organisations).

d. Institute for essential services reform (IESR)

The last social and environmental-related stakeholder is the Institute for Essential Services Reform (IESR). IESR is a brain-trust organisation that focuses on energy and environmental issue in Indonesia. The organisation's vision is to build a better, more sustainable, low-carbon oriented world and energy production for the future generation. IESR aims to encourage Indonesia's energy transition towards a sustainable energy system. Various programs are carried out by IESR, including research, policy advocacy, public campaigns, energy development assistance, capacity building and strategic partnership with non-governmental actors (IESR, 2022). For instance, in 2022, IESR, in collaboration with MEMR, held the Indonesia solar summit (ISS) 2022 with the central theme of "*Bringing the gigawatt order of solar energy to Indonesia*". Workshop, conference and discussion with main stakeholders such as PT.PLN, MEMR, private companies, researchers and users were conducted during the event (ISS, 2022).

4.3.4. Stakeholders related to technology

The current stakeholder focuses on research and development of rooftop PV technology in Indonesia. This section briefly explains two main stakeholders in this sector: (1) University and (2) the Government agency.

a. University

Universities, such as the Bandung Institute of Technology (ITB) and the University of Indonesia (UI), are stakeholders who have numerous sources of knowledge and play an essential role in conducting research by applying science and technology to develop solar PV technology. At ITB, the New and Renewable Energy Research Centre (PPEBT ITB) was established to play an active role in responding to the challenges of renewable energy in Indonesia. Besides contributing to research and development, other activities, including workshops, seminars, and publications, are conducted by this research centre (Bandung Insitute of Technology (ITB), 2022). Meanwhile, at UI, Tropical Renewable Energy Center (TREC) was established in 2015. In collaboration with scientists worldwide, TREC focuses on the topic of renewable energy applications in the tropics (University of Indonesia, 2022).

b. Government agency

State-owned research and science agencies, such as the Indonesian Institute of Sciences (LIPI) and the National Research and Innovation Agency (BRIN), are essential stakeholders in researching and developing rooftop PV technology in Indonesia. For instance, LIPI formed a research group, namely the Materials and Devices for Solar Cells (MDSS), focusing mainly on developing materials synthesis and device fabrication for solar energy applications (Indonesian Institute of Sciences, 2022). BRIN is a non-ministerial government agency under and responsible to the President of Indonesia. BRIN focuses on improving the local technological capability, local innovation, local research and the quality of human resources in science and technology, such as renewable energy technology (National Research and Innovation Agency, 2022).

4.3.5. Value chain related stakeholders

Porter (1985) defines the term value chain to refer to a set of business activities or processes that a firm operates in delivering products or services to the end customer. This section explains all stakeholders involved directly in Indonesia's rooftop PV value chain. Wide-range stakeholders have been identified, including the state electricity operator, rooftop PV developers, technology providers, rooftop PV users, and consumers.

a. Electricity system operator

Indonesia's electricity system has been predominantly managed by the state-owned electricity company, PLN. With the motto "*Electricity for a Better Life*", PLN, represented by its core business line, has been involved in all of Indonesia's electricity value chains, namely generation, transmission and distribution (PLN, 2022). The role of PLN in Indonesia's electricity system is considered critical due to its significant share ownership of power plants and the responsibility of handling the majority of the transmission and distribution system (Tarigan, 2020). Besides PLN, power generation is also conducted by private companies or foreign parties usually called Independent Power Producers (IPP). Since 1985, the government has provided IPP access to contribute to power generation in Indonesia. However, IPP is not allowed to participate in transmission and distribution systems, where PLN remains the only stakeholder managing the majority of the electricity system (except for the remote areas where IPP is allowed to distribute electricity) (Paryono et al., 2020). Therefore, regarding the rooftop PV development, PLN manages all electricity systems in Indonesia, including giving permission or rejecting rooftop installation.

b. Rooftop PV developers

The rooftop PV developers are defined as an organisation or a person who determines and manages the majority of processes of rooftop PV installation. Processes such as investment feasibility analysis, project financing planning, permission issues from the government, land acquisition problems or other regulatory-related problems are managed by developers (Xurya, 2022). In Indonesia, numerous companies are involved in the rooftop PV industry, such as PT. Empat Mitra Indika Surya, Xurya Solar, ATW Solar, SUN Energy, Akuo Energy, TML Energy, and Syntek Energy.

c. Technology manufacturer (Supplier)

Technology manufacturers are stakeholders that provide the technologies needed for rooftop PV installation, such as PV modules, inverters, mounting systems, and other necessary components. These components have a considerable influence on the quality of rooftop PV

(Xurya, 2022). Various technology companies, including local and global manufacturers, are involved in rooftop PV in Indonesia. For instance, local companies like SKY Energy, Solar Quest and PT. LEN Industry provides inverter and solar PV. Furthermore, global companies such as Seraphim, Sungrow, Canadian solar, and Huawei supply inverters, solar modules, and monitoring systems.

d. Engineering, Procurement, and Construction (Installer)

Engineering, Procurement, and Construction, abbreviated by EPC or usually called the installer, are the stakeholders who proceed the value chain of rooftop PV into the construction phase. These companies are responsible for designing, component procurement, construction, and commissioning rooftop PV (Xurya, 2022). TML Energy, ICA Solar, Surya Energi Indotama (SEI), and LEIN Power are examples of EPC companies in Indonesia.

e. Rooftop PV users (owner)

Users or owners are defined as the stakeholders entitled to the ownership of the rooftop PV after the completion of construction or reaching the point of commercial operation (Xurya, 2022). Moreover, the users or owners are responsible for the process and maintenance of the solar system. Rooftop PV users or owners can be individuals, factory owners, companies, or building developers. In general, rooftop PV users in Indonesia are classified into two: (i) Household and (ii) Industrial users.

i. Household

A household is an individual who adopts rooftop PV. According to MEMR, up to May 2021, the number of users who have adopted rooftop PV was 3.781 households. Compared to November 2018, when only 592 users adopted rooftop PV, this number shows the acceleration of rooftop PV diffusion in Indonesia (Jelita, 2021).

ii. Industrial users

Many companies in Indonesia have adopted rooftop PV in their factories or offices. For instance, in Jakarta, companies such as Bika Living, PT Bukit Jaya Semesta, Ciputra World II Jakarta, Grand Hyatt, and Tokopedia have used rooftop PV to support the government's renewable energy target in 2025 (Nugraha, 2019). Another example of the industrial user is Coca Cola of Indonesia and Aqua Danone. Coca Cola of Indonesia has decided to install 7.13 MWp rooftop PV in a factory located in West Java. This installation is predicted to be the largest rooftop PV in Southeast Asia. Meanwhile, in Central Java, Aqua Danone has adopted rooftop PV with a capacity of 2,919 MW (DEN, 2021).

f. Electricity Consumers

Electricity consumers are the stakeholders who consume the electricity produced from various power generation, including rooftop PV and distributed by the electricity system operator (PLN). According to PLN (2020), electricity consumers can be classified into six groups based on electricity tariff, which are (1) households, (2) businesses, (3) industries, (4) social, (5) government-owned offices, and (6) public street lighting. In 2020, the household is the primary demand for electricity with 46.04% of total consumption (243.582,75 GWh), followed by industry (29,66%), business (17.58%), Social (3.32%), government-owned offices (1.9%), and public street lighting (1.49%).

4.4 Policy and Regulation

4.4.1. Electricity Law

The history of electricity law in Indonesia began in 1890 when the power system was supervised according to an 1890 Dutch regulation called “Installation and Utilization of Conductors for Electrical Lighting and Transferring Power via Electricity in Indonesia”. This ordinance was annulled and replaced by the 1985 Electricity Law, representing the new era of the electricity sector in Indonesia. Under this law, a centralised arrangement was established with a state-owned electricity company (PLN) as the only holder over electricity transmission, distribution, and sale (ADB, 2020).

The 1985 Electricity Law allowed private or foreign investment to participate in the power generating sector as an independent power producer (IPP). Essentially, this model was carried out under a power purchase agreement (PPA), which allowed IPP to sell their power solely to PLN. However, during the 1997 Asian crisis, which decreased the financial capability of PLN, the liberalisation of the electricity sector in Indonesia started (Paryono et al., 2020). The Government of Indonesia established the new Law No.20 of 2002, which became the first formal regulation to deescalate the exclusive powers of PLN. This law provides equal access for private parties to contribute to the electricity system (Maulidia et al., 2019).

Despite the contribution to creating a collaborative ecosystem in the electricity system in Indonesia, Law No.20 of 2002 was annulled by Constitutional Court (MK) on 21 December 2014. A judicial review submitted by several non-governmental organisations considered that Law No.20 of 2002 was contradictory to the Indonesian Constitution. Article 33 of the 1945 Indonesian Constitution mentions that the state has the right to control all resources, including electricity, to fulfil the needs of greater people (ADB, 2020).

Furthermore, to achieve the target of the renewable energy mix, the government has aggressively created efforts to establish new regulations that support the development of renewable energy. For instance, in 2009, the government launched a new electricity law No.30 of 2009. Under this law, the government provides more significant opportunities for IPPs to participate in the electricity industry sector. While this law facilitates the participation of private parties, it also reaffirms the role of PLN as the primary stakeholder in managing electricity generation and the sole party managing the transmission, distribution, and provision of supply to the public (Setyowati, 2020).

4.4.2. Rooftop PV Business Policy

This section describes the policies made by the government to regulate the business actor in the rooftop PV industry in Indonesia. According to Government Regulation No. 30 of 2009 on electricity, the rooftop PV business actor must fulfil several requirements. Those requirements are explained according to the socialisation event conducted by MEMR (MEMR, 2020).

- Operation License (IO)
  According to MEMR Regulation No. 13 of 2019, all customers of PLN who carry out the construction and installation of a rooftop PV system are required an operation license (IO). Unit business, including power generation like rooftop PV, requires an operating permit issued by the ministry or provincial government. IO from the ministry is necessary when the operational area covers more than one province. Meanwhile, IO from the local government is required when the operating area is located within one province. Moreover, according to this law, an operation license is only necessary for a captive power plant with a capacity of > 500kVA. For capacity up to 500kVA, report submission to MEMR or the government is required before the installation (PwC Indonesia, 2021).
- Installation Permit
  An installation permit is an approval issued by PLN, as the majority electricity operator, which the user must obtain before installing rooftop PV. According to the MEMR Regulation No. 26 of 2021, PLN and other operator companies in Indonesia need to issue the approval or rejection of a customer application within five business days after receiving the application. In the previous regulation, the timeline was 15 business days.
- Business Entity Certificate (SBU)
  Every business entity in Indonesia must have a business entity certificate (SBU) as proof of recognition of the competence of a business entity according to business classification and qualification. The SBU is valid for a company as a reference to participate in the pre-qualification of tenders or auctions, for example, an auction in Government agencies. Developers, EPC companies, suppliers, or consultants need SBU before starting the business process.
- Electricity Power Support Service Business License (IUJPTL) (MEMR, 2020).
  Besides SBU, the organisation participating in rooftop PV development in Indonesia need to have IUJPTL. According to MEMR No.35 of 2013, the IUJPTL is granted in accordance with the classification, qualifications, and certificates owned by the business entity. The central or provincial governments issue the IUJPTL based on company characteristics. In the case of a company whose majority share is owned by another country, the central government publish the IUJPTL. Meanwhile, in the case of a company whose majority share is owned by Indonesia, the provincial government provide the IUJPTL (MEMR, 2020).

- Operation Eligibility Certificate (SLO)

  A certificate of operation eligibility (SLO) is proof of formal acknowledgement of an electrical power installation that has functioned according to the specified requirement and is declared fit for operation. The SLO is fulfilled by having the manufacturer's test results, product certificates or equivalent product safety standard documents. Moreover, according to MEMR No. 12 of 2019, only rooftop PV with a capacity of 500 kVA needs to acquire SLO (MEMR, 2020).
- Indonesia National Standard Certificate (SNI)

  The SNI is drafted by the National Standardization Agency of Indonesia (BSN) and must be complied with every product produced or imported into Indonesia. Compliance with SNI is mandatory for every product intended to be traded in Indonesia. For example, since January 7, 2021, the government has issued rules on SNI mandatory for all PV modules, including crystalline silicon. To adjust the innovation of science and technology in the renewable energy sector, the government stipulated this regulation through MEMR No.2 of 2021 (SNI, 2022).

CHAPTER 5 – MULTI-LEVEL PERSPECTIVE ANALYSIS

5.1 Sociotechnical landscape

The development of rooftop PV in Indonesia is influenced by multiple landscape factors such as rural development and electrification, the economic crisis of 1997-1998, climate change, energy security, international and market pressure, and the COVID-19 pandemic. These factors were identified to influence niche and regime actors directly. Meanwhile, niche and regime actors do not affect these factors. This section explains the landscape factor influencing the rooftop PV niche and regime actors..

5.1.1. Rural development and electrification

In the early stage of rooftop PV introduction, in the 1990s, approximately 18 million families in Indonesia could not access electricity. More than 37,000 villages and an estimated 140 million people lacked electricity connections. Meanwhile, other towns were only provided with electricity for limited hours (6-12 hours a day) due to the limitation of the capacity of the power station. In 1993, although the total capacity had increased by 9,118 MW, the electricity supply could not meet the demand due to the rapidly growing demand (de Quay, 1994). According to the central bureau of statistics of Indonesia, the percentage of the population with access to electricity was 51.83% in 1993. The share increased to 89.47% in 2010 (Central Bureau of Statistics of Indonesia, 2022). The following figure shows the percentage of Indonesia's households with electricity access from 1993-2021.

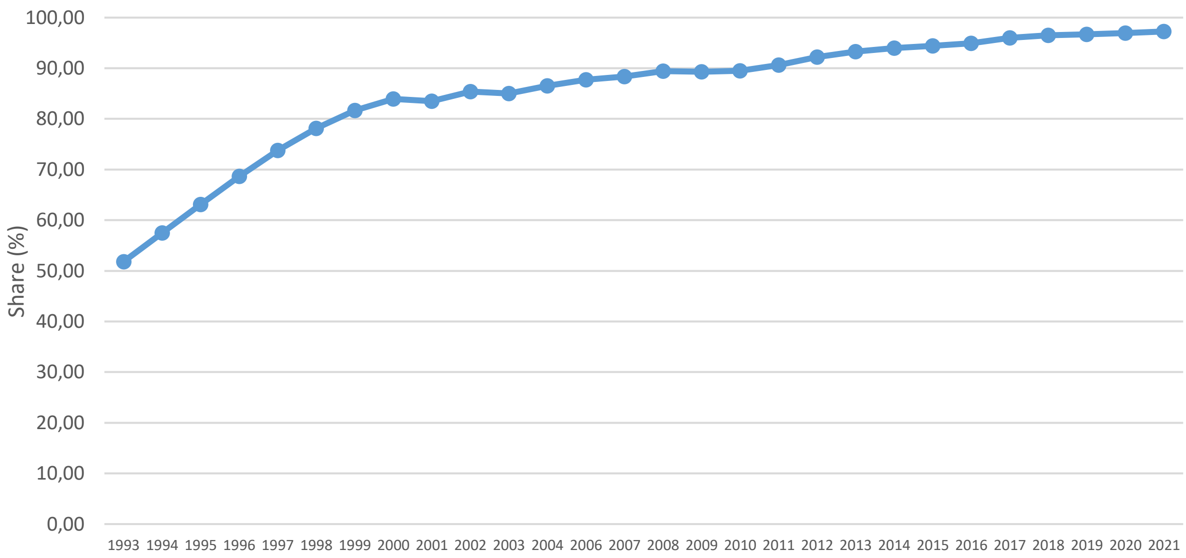

Figure 13 Share of the population access to electricity, 1993-2021 (Central Bureau of Statistics of Indonesia, 2022).

The lack of rural development and electrification encouraged many stakeholders (government and non-government) to solve this issue. For instance, the first rooftop PV project, known as the solar home system in Sukatani village West Java, was achieved by cooperation between three organisations: R&S

Renewable Energy System (recently Shell Solar Energy), the Directorate General of International Co-operation of the Netherlands (DGIS) and government agency. The project aimed to become a pilot project to develop electrification in rural areas using PV technology such as rooftop PV in the solar home system (Reinders & Sudradjat, 1999). Furthuremore, following the success of the Sukatani project, the government established the national development plan 'Repelita V' to accelerate the diffusion of the solar home system as a plan for rural development and electrification. The government provided a financial incentive ($1.65 m) which resulted in the installation of 3250 solar systems during 1991-1992. Subsequently, in the next national development plan, 'Repelita VI', the new rural electrification development was announced by a project called "Fifty Mega Watt peak Photovoltaic Rural Electrification". The project aimed to install PV in 1 million rural households, rural health clinics, support water pumps, and television stations (de Quay, 1994).

Another action was taken by non-government organization like World Bank. The rural development and electrification factor motivated World Bank to support the use of rooftop PV in the solar home system. The World Bank found that rural households were willing to pay for a solar home system in the absence of grid connection. Through Global Environment Facility (GEF), World Bank was was offering loan incentives and trageted 200,000 units of PV systems (Miller & Hope, 2000).

5.1.2. The economic crisis 1997-1998

The economic crisis of 1997-1998 was a major global financial crisis that started in Asia and disrupted the world economy at the end of the 1990s. The crisis was caused by the devaluation of the currency exchange rate and a massive bubble in the capital. The crisis started in Thailand in July 1997 due to the depletion of foreign currency to support the Thai baht currency peg to the U.S Dollar. It impacted the collapse of the Thai bath valuation, and the government was forced to float the currency value (D. Ba, 2021). The crisis spread immediately to the neighbour country such as Indonesia. In the next six months, the Indonesian rupiah's valuation was significantly down by 80 per cent. And the Indonesian GDP per capita collapsed by 43.2 per cent. The impact of the financial crisis on Indonesia was not only on the economic sector but also on the political sector. The Indonesian president at the moment, Soeharto, was forced to resign from his Presidency (Corporate Finance Institute, 2022).

The turbulence in the economic and political sector during the financial crisis impacted many development projects in Indonesia, including rooftop PV development in rural development and electrification project. For instance, the World Bank rural development project declared just before the financial crisis was hampered by the situation. Due to the high inflation, high-interest rates, GDP collapse, and uncertainty of the future, the consumer was demotivated to use the loan from the world bank for PV installation. Furthermore, because of the paralysis of the economic sector, financial institutions like banks could not provide loans to solar system companies (World Bank, 2001). Moreover, the currency devaluation increased the imported PV modules prices to roughly 50 per cent

(Miller & Hope, 2000). Consequently, the project was deescalated and only able to install 1,349 units of the solar system (World Bank, 2001).

5.1.3. Climate change

Climate change influences rooftop PV development through its impact on regulation and policy of the energy development plan in Indonesia. The influence can be seen through Indonesia's commitment to the Paris Agreement. As outlined in Nationally Determined Contribution (NDC), Indonesia aims to contribute to the collaborative effort to prevent a 2℃ increase in global average temperature (Ministry of Environment and Forestry, 2021). One official government mentioned:

> *"Indonesia's aim to reduce greenhouse gases refers to the government's commitment (NDC) to reduce 29% (own capacity) and 41% (with international assistance) emissions in 2030. One of the strategies we take from the energy sector is encouraging renewable energy and energy conservation."* (Interviewee #12, 2022)

The renewable energy strategy is represented in the renewable energy target of 23% by 2025 and 31% by 2030. The government has implemented several strategies to achieve this target, including rooftop PV development. Through the MEMR Regulation No.49 of 2021, the government seeks to accelerate the adoption of rooftop PV by increasing the kWh export-import multiplier from 65% to 100% (PwC Indonesia, 2021). In the following statement, the official government also stated that rooftop PV is one of the government strategies to achieve its RE target in 2025.

> *"To achieve 23% RE in the 2025 target, and we are already in 2022, where our current achievement of approximately 11%, we must have extraordinary efforts. The government hope that rooftop solar PV will be one of the government's efforts to encourage the development of RE."* (Interviewee #12, 2022)

The central government also issued instruction letters to the provincial government to install rooftop PV in state-owned buildings, such as offices, schools, and hospitals. This action is carried out to promote rooftop PV adoption and support the achievement of the renewable target of 23% by 2025. The official government stated:

> *"The Ministry announced that every government building uses rooftop PV so that it becomes an example and marketing for the wider community. The government also issued a letter to local governments to use rooftop PV."* (Interviewee #12, 2022)

Furthermore, climate change also influences global organisations' activities, including the United Nations. To support sustainability worldwide, UNDP collaborates with MEMR through a project called Market Transformation for Renewable Energy and Energy Efficiency (MTRE3) to provide incentives for rooftop PV development in Indonesia. The official government explained:

"One of the efforts to encourage rooftop PV adoption is a program with UNDP assistance, namely the sustainable energy fund (SEF), such as cashback given to rooftop PV consumers. It is hoped that the use of this rooftop will become more economically attractive." (Interviewee #13, 2022)

This Sustainability Energy Fund (SEF) incentives, allocated from the Global Environment Facility (GEF), are expected to boost rooftop PV investment to achieve its economic value. Thus, it can trigger the market's willingness to adopt rooftop PV massively(United Nations Development Program, 2022).

5.1.4. Energy security

Besides climate change, energy security is another more significant challenge and priority for Indonesia to ensure energy supply for continued economic growth. As mentioned by the official government:

"The concern of the directorate general of EBTKE is the development of renewable energy and energy conservation to increase energy security and energy independence. Currently, most of Indonesia's supply comes from fossils or non-renewable energy. Due to Indonesia's decreasing amount of fossil resources, we have to import resources from other countries to ensure energy availability. Therefore, the government encourages renewable energy development to ensure energy sustainability in Indonesia" (Interviewee #13, 2022)

As shown in the following table, the energy source in Indonesia is dominated by non-renewable energy. In 2021, only 12.16% of the energy mix comes from renewable energy. The other proportion comes from non-renewable energy such as oil (33.4%), coal (37.62%) and gas (16.82).

Table 10. Share of primary energy supply (MEMR, 2021a, p. 11)

Type of Energy	2017	2018	2019	2020	2021
Oil	41.43%	38.72%	34.97%	32.75%	33.40%
Coal	30.52%	32.99%	37.31%	38.52%	37.62%
Gas	21.39%	19.68%	18.52%	17.46%	16.82%
Renewable Energy	6.66%	8.6%	9.19%	11.27%	12.16%

Indonesia is known as the largest exporter of steam coal globally and one of the biggest exporters of LNG (liquefied natural gas). In contrast, although oil is the second contributor to the primary energy supply, the declining oil production since 2004 and rising domestic demand are an increasing concern for Indonesia to ensure energy security. To meet about half of the domestic market, Indonesia currently imports petroleum products and has become a net oil importer since 2004 (EIA, 2020). Figure 14 shows Indonesia's oil production and consumption from 1965 to 2021.

As quoted by the government, the current energy condition, where the production of domestic resources cannot meet the domestic demand and is still dependent on other countries, motivates the government to develop renewable energy, including rooftop PV. The development of renewable energy technology is expected to become one of the strategies to ensure Indonesia's energy security and independence.

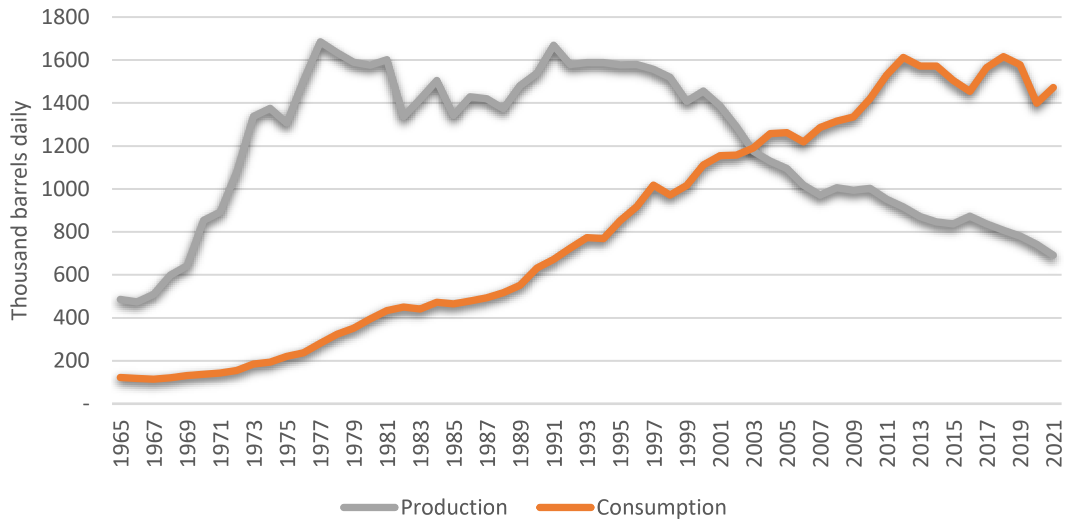

Figure 14 Oil production and consumption 1965 – 2021 (BP, 2022).

5.1.5. International and market pressure

Pressure from international communities and the market on the industrial sector pushes rooftop PV diffusion in Indonesia. One sustainable financer from a financial institution and one technical advisor from an energy company in Indonesia mentioned:

> *"The first factor influencing rooftop PV development is International pressure to transform the green industry, which can be evaluated through the ESG level. This is pressure for companies, especially multinational companies."* (Interviewee #9, 2022)

> *"The Paris agreement also helps the rooftop PV development, where we cannot be separated from the ESG (Environmental, Social and Government) score. The ESG score is an assessment of a company based on how friendly they are to the environment, close to the surrounding community, and friendly to development. It has respective assessments for these three aspects. And this helps them to get more funding. Investors now have a higher awareness of the environment and sustainability, so they choose companies with a higher score. And foreign investors require and strive for high ESG, such as my company, one of which is to reduce the greenhouse carbon generated by activities and businesses."* (Interviewee #4, 2022)

As mentioned in the previous statement, ESG (Environmental, social and governance) score is increasingly recognised as a global standard to evaluate a company's behaviour and business activities towards sustainability. ESG was launched by the UN in 2015 as a collaborative strategy for value creation to generate prosperity, peace, and sustainability worldwide (PwC, 2021). According to MSCI (2021), many investors are currently considering ESG scores in investment analysis. 79% of Asia-

Pacific investors reported moderately or significantly increasing investment in ESG. Due to the growing trend of including ESG in investment analysis, companies are forced to renew business activities to achieve a higher ESG score. This factor influences many companies, especially multi-companies, in Indonesia to adopt rooftop PV as one strategy to reduce greenhouse carbon.

Another pressure to use rooftop PV is from the market. The official government state:

> *"From the industrial sector, there are demands from their HQ (headquarters) and their consumers to be able to produce green products. One of the strategies to make the green product is by producing green electricity. This is also one factor that supports the development of solar rooftop PV. So that industries are very interested in taking advantage of solar PV to support the provision of electricity sources."* (Interviewee #12, 2022)

To be competitive in the global market, companies in Indonesia are forced to meet the obligation of carbon's economic value, such as carbon tax prices and the EU's carbon border adjustment mechanism. Especially for companies producing products exported to other countries like Europe, the US, and Japan (IESR, 2021). According to PwC (2021), the carbon border is designed to encourage trading partners of the EU, including Indonesia, to decrease the carbon leakage and emission-heavy import to the EU. The carbon border regulation is predicted to limit the trade between Indonesia and the EU due to additional taxes on products that exceed the carbon footprint limit (IESR, 2021). Furthermore, the research conducted by WWF and The Economist Intelligence Unit (2021) shows a significant change in consumers' behaviour. The research shows that since 2016 consumers searching for sustainable goods are increasing globally by 71%. As quoted by the official government in the previous statement, companies in Indonesia are currently demanded by headquarters (HQ) and consumers to produce sustainable products, which motivates companies to produce green electricity by utilising rooftop PV.

5.1.6. COVID-19

The coronavirus disease 2019 (covid-19) is a respiratory illness firstly reported in China at the end of 2009. The World Health Organization (WHO) declared the covid-19 as a global pandemic on 11 March 2020 after the virus spread to more than 110 countries and 118,000 confirmed cases worldwide (Safitri et al., 2021).

The spread of the global covid-19 pandemic that began in early 2020 put much pressure on multiple stakeholders, including the government and private entities, to respond to the pandemic effect. Many countries' national governments have applied several measures, such as a lockdown policy, to mitigate the pandemic spread. According to Zhang et al. (2021), the covid-19 lockdown policy influence many aspects of PV diffusion: (1) the lockdown policy disrupts and stop many activities in the PV supply chain, e.g. installation, distribution and rental. (2) Because the lockdown policy disarranges economic activity in the industry and residential sector, which creates uncertainty in the market, many users of PV choose to postpone and terminate the installation project. (3) lastly, the covid-19 may potentially jeopardise the international commitment to climate change due to the loss of emissions during the lockdown.

Even though the study on the effect of a covid-19 pandemic on the PV market and supply chain is rarely found (Zhang et al., 2021), several interviewees mentioned several impacts of the pandemic on the rooftop PV market in Indonesia. Those impacts are explained as follows:

Disrupt the supply chain

Two interviewees stated that rooftop PV disrupted the solar PV logistic due to the lockdown policy by the local and international governments. First, Interviewee #8 (2022) says that the local manufacturers had difficulty finding operating ports due to the lockdown policy. Due to this problem, the logistics took three times longer to ship the product during the lockdown. However, the interviewee added that the effect of covid-19 on supply chains is gradually diminished due to the measures employed by the government (Interviewee #8, 2022). Secondly, Interviewee #1 (2022) mentioned that the covid-19 disrupts the supply chain from PV importer countries such as China, which increases the PV price. The following quote is the complete statement by Interviewee #1 (2022):

> *"There are problems in its implementation when COVID has a domino effect on solar PV. Such as the effect of COVID on the supply chain from China, which has an impact on price increases. Due to the covid, the price suddenly rose. And we don't know when the price will go down, especially now that China (Shanghai) is in lockdown."* (Interviewee #1, 2022)

Increase uncertainty in the market

The second impact of covid-19 on rooftop PV diffusion is increased market uncertainty. Interviewee #8 (2022) explained that the users commonly consider rooftop PV installation a long-term investment. The long-term contract between the PV providers and users generally becomes the additional factor that demotivates users in utilising rooftop PV. With the increased market uncertainty due to the covid-19, many users are currently hesitant to have a long-term contract with the PV provider company. Interviewee #8 (2022) further explain:

> *"The client is not sure whether to give a 25-year contract, whether in 25 years the company is still operating or not. Many questions like this are related to Covid-19 and the weakening of the country's economy." (Interviewee #8, 2022)*

Both impacts align with the explanation by Zhang et al. (2021) regarding the effect of the covid-19 lockdown on the PV market

5.2 Regime analysis

This section discusses regime-level factors such as actors and institutions, regulation, technical elements, and user and market preferences influencing Indonesia's rooftop PV development.

5.2.1. Actors and Institutions

From 1967 - 2006

The first use of rooftop PV was introduced during the second President’s term, Soeharto, who led Indonesia for 31 years, from 1967 until his resignation in 1998. During his period, the government launched the development of rural electrification through national development plans called Repelita (explained in section 5.2.2). In the fifth Repelita and sixth Repelita, rural electrification using solar PV was introduced to the public after the pilot project in Sukatani village (de Quay, 1994).

In 1981, National Energy Coordination Agency (BAKOREN) was responsible for arranging Indonesia's energy sector. BAKOREN was formed with the minister of MEMR as the chairman. The members of BAKOREN consisted of the Minister of Industry, Minister of Transportation, Minister of Finance, Minister of Environment, Minister of Research and Technology, Minister of National Development Planning and Head of National Nuclear Energy Agency (DEN, 2022).

From the 2007- Present

.In 2007, National Energy Council (DEN) was introduced as a replacement for BAKOREN. DEN is responsible for designing and formulating a national energy policy, establishing a national energy plan, and supervising policy implementation. DEN members consist of seven ministers and eight stakeholders from various sectors. The seven ministers are the Minister of Finance, Minister of National Development Planning, Minister of Transportation, Minister of Industry, Minister of Agriculture, Minister of Research and Technology, and Ministry of Environment and Forestry. Meanwhile, the eight stakeholders consist of two stakeholders from academia, two stakeholders from industrial sectors, two stakeholders from the consumer side, one stakeholder from technological experts, and one stakeholder environmental side. The chairman of DEN is the President, with the vice-president as the vice-chairman and the minister of MEMR as the daily chairman (DEN, 2022).

Furthermore, the development of renewable energy was mainly arranged by the MEMR, which currently focuses on supervising renewable energy development to achieve a 29% emission reduction in 2025 (MEMR, 2022). Two divisions in MEMR are essential in renewable energy development. The first division is the director-general of renewable energy and energy conservation which is responsible for arranging all activities, policies, norms, standards, and criteria regarding renewable energy and energy conservation. Another division is the director-general of electricity which manages the electricity sector in Indonesia (Yudha & Tjahjono, 2019).

Another regime institution influencing rooftop PV development is the state-owned grid company PLN which operates most of Indonesia's electrical activities, including distribution, transformation, and power plan. Moreover, according to the policy, the customer or provider companies need to acquire approval from PLN before the installation starts. (Ashurst, 2021). Therefore, this section concludes that the actors and institutions at the regime level are the government, PLN, private companies, cooperatives and international financial support like the world bank.

5.2.2. Formal Rules and Policy

From the 1980s – 1998

The development regime in Indonesia started with the introduction of the 'New Order' under the President of Soeharto in 1967. During the Soeharto regime, Indonesia had a long-term national development plan divided into six five-year development plans (*Repelita*): *Repelita* I (1969-1974), *Repelita* II (1974-1979), *Repelita* III (1979-1984), *Repelita* IV (1984-1989), *Repelita* V (1989-1994), and *Repelita* VI (1994 – unfinished due to president resignation in 1998).

- Repelita I (1969 – 1974) focused on food security and agricultural sector establishment
- Repelita II (1974 – 1979) focused on infrastructure (outside Java) and primary industry development
- Repelita III (1979 – 1984) focused on food self-sufficiency and labour-intensive industries to increase exports
- Repelita IV (1984 – 1989) aimed to create new jobs and establish the industry sector
- Repelita V (1989 – 1994) aimed to develop the transportation, communication and education sector
- Repelita VI (1994 – 1998) focused on foreign investment development and boosting the national economy and industry

The objective of Soeharto's development plan was presented in the development trilogy: (1) High economic growth, (2) Distributive development policy to achieve social equity, and (3) National stability (Aswicahyono et al., 2009). In 'Repelita V' and 'Repelita VI', the Soeharto regime launched a formal policy to encourage rural development and electrification. The government announced the president's financial incentives ($1.65 m) and the government's project called "Fifty Mega Watt peak Photovoltaic Rural Electrification", respectively, to support rural development and electrification by utilising rooftop PV technology (de Quay, 1994).

During the first five-year development plan, the government declared the first subsidies on fuel. These subsidies aimed to support macroeconomics and stabilise the social and political condition (Beaton & Lontoh, 2010). In 1981, BAKOREN formulated a General Policy and Energy (KUBE) to increase the utilisation of energy resources. KUBE was revised three times in 1987, 1991 and 1998. During this revision, the focus of energy policy in Indonesia is transformed from the escalation of oil production in the 1980s, the diversification of energy resources from oil to coal and energy conservation in the 1990s, and the shift the energy sources to clean energy in 1998 (Maulidia et al., 2019). The revision of KUBE in 1998 was the first policy that mentioned renewable energy as the priority of development in Indonesia (BPPN, 2012).

From 1998 - 1999

The economic crisis in 1998, which also resulted in the resignation of the Soeharto government, significantly changed Indonesia's development policy. The development trilogy formulated by Soeharto's regime was no longer used. In the post-Soeharto governments, the development of Indonesia was focused on the recovery from the economic crisis (Aswicahyono et al., 2009). From 2000 to 2019, Indonesia's economy was significant growth, with average GDP growth of 5.26%, as shown in the following figure

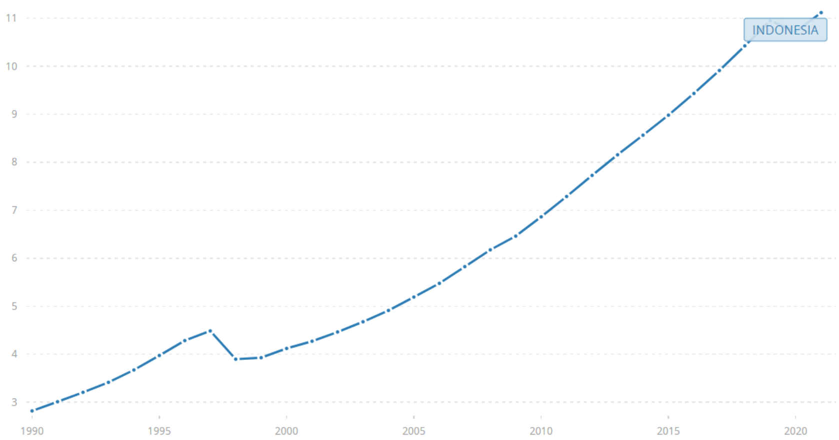

Figure 15 Indonesia's GDP from 1990-2021 (axis X: Quadrillion, Y: Year) (Reprinted from World Bank (2022)

From 1999 – Present: Energy Policy in Indonesia

In the post-financial crisis era, the National Energy Policy (KEN) was established by DEN in 2003 as a formal national and regional energy plan development guideline, including renewable energy development. In 2006, the sixth Indonesian President, Susilo Bambang Yudhoyono, mandated KEN to increase the renewable energy percentage in the energy mix by aiming at a 17% share in 2025. The President ordered it due to the energy security issue after Indonesia became an oil net importer in 2004 (Maulidia et al., 2019).

In 2014, a new revision of KEN was formulated. The policy is influenced by Indonesia's commitment to the Paris Agreement. Through the Nationally Determined Contribution (NDC) 2021, Indonesia is committed to reducing greenhouse gas emissions by 29% (voluntarily) or 41% (with international support) by 2030 (Ministry of Environment and Forestry, 2021).

To implement KEN, the National Energy Plan Development (RUEN) and the Regional Energy Plan Development (RUED) were formulated as the description of strategies or stages of achieving the KEN target and the detailed location of the program to be carried out. The target of KEN is described as follows (DEN, 2006):

- The renewable energy target in the energy mix is to reach 23% by 2025 and 31% by 2030.
- To achieve Indonesia's electrification ratio of 95% by 2025.

Furthermore, the target of RUEN is presented as follows (MEMR, 2017b):

- The renewable energy target is 23% by 2025 and 31% by 2030 in the energy mix.
- The electrification ratio of approximately 100% by 2020.
- The electricity generation capacity is targeted to reach 115 GW by 2025 and 430 GW by 2050.
- The electricity consumption aims to reach 2,500 kWh/capita by 2025 and 7,000 kWh/capita by 2050.

Besides being influenced by the international Paris agreement, KEN is also navigated by Indonesia's Sustainability Development Goals (SDGs). Through Presidential Regulation no 59 in 2017, the Ministry of National Development Planning is mandated to arrange the Roadmap of SDGs in Indonesia. As described in Goals 7 of Indonesia SDGs, concerning affordable and clean energy, the electric power consumption is set to reach 2,035 kWh in 2030 (business-as-usual scenario) or 3,201 kWh in 2030 (with intervention scenario). This goal is represented in the KEN regarding the target of electrification ratio 95% by 2025 and in the RUEN regarding the target of consumption capacity: 2,500 kWh/ capita by 2025 and 7,000 kWh/capita by 2050. Furthermore, the other target of SDG concerning cleaning energy is to have 12.1% renewable energy in the energy mix in 2030 (business-as-usual) or 26.1% renewable energy in the energy mix in 2030 (with intervention ratio). This goal is included in KEN and RUEN goals concerning the renewable energy target: 23% by 2025 and 31% by 2030 (Bappenas, 2019).

Solar Energy Policy in Indonesia

To elevate the solar PV deployment in Indonesia, the MEMR introduced a feed-in-tariff (FiT) scheme with MEMR Regulation No. 17 of 2013. The feed-in tariff (FiT) is a financial mechanism to accelerate investment in renewable energy technologies by incentivising renewable energy producers. Moreover, to support the local manufacturing industry, the MEMR Regulation No. 17 of 2013 stipulated different tariffs based on the portion of local content (TKDN). This regulation ensured projects with higher local content (using modules with > 40% local content) received higher rates (US$0.30/kWh). Meanwhile, the projects with lower local content (using modules with < 40% local content) received lower tariffs (US$0.25/kWh) (Hidayatno et al., 2020).

As mentioned in the previous chapter, the FiT mechanism was only implemented in a short period from 2013 to 2014 due to legal action by APAMSI. This legal action by APAMSI was motivated by the impartiality of the regulation towards the local manufacturers. APAMSI wanted to ensure solar PV is entirely produced from local producers and materials. Subsequently, MEMR revoked the regulation in 2015 and cancelled all plans, including the FiT mechanism (Hamdi & IEEFA, 2019).

After the solar energy policy deterioration, the MEMR established a new MEMR Regulation No. 50 of 2016. This regulation published a well-priced FiT mechanism for the solar IPPs and was expected to boost solar energy dissemination. The FiT tariffs in this regulation were decided in a range between US$ 0.145/kWh and US$ 0.25/kWh depending on the project location. However, this regulation was hindered and revised following the appointment of the MEMR's minister in early 2017 (Hidayatno et al., 2020).

After considering the impact of the FiT scheme on the rapid increase in PLN's fixed generating costs, a new regulation No 50 of 2017 was announced with the new FiT scheme tariffs. This regulation states the tariff is determined by systematically comparing it with the applicable Electricity Generation Cost (BPP). The regulation also emphasises that the rate must not be lower than the national BPP or no more than 85% of regional BPP, which ranges between US$ 0.048/kWh – US$0.144/kWh, depending on the location (Hamdi & IEEFA, 2019).

At the end of November 2018, the MEMR Regulation No.49 of 2018 was issued to support the rooftop solar PV development. This regulation established a net metering scheme for users with excess available power. The net metering scheme puts the excess available power to the owner's credit. The balance is accumulated for up to three months before expiration. Moreover, this regulation values exported electricity at 65% (Hamdi & IEEFA, 2019).

The latest regulation of solar energy is MEMR Regulation No. 26 of 2021 on the rooftop solar power plant, which revoked the MEMR Regulation No.49 of 2018. Under this regulation, the export-import kWh multiplier increases from 65% to 100%. This increased rate of kWh multiplier encouraged renewable energy development by utilising more rooftop solar power plants. Moreover, the accumulation system for any excess available power rises from three to six months (PwC Indonesia, 2021).

Another significant regulation in rooftop PV development is the local content level (TKDN). In 2019, the local content for rooftop PV increased from 50% to 60% (Hamdi & IEEFA, 2019). However, the 60% TKDN level creates complexity in the rooftop PV implementation due to the lack of local manufacturing capability. The local manufacturers can only reach 43% (below the regulation). Therefore, local content regulation sets a high threshold for stakeholders to install rooftop PV (Interviewee #10, 2022).

5.2.3. Material and Technical Elements

According to the IEA (2022), Indonesia's electricity generation reached 35 TWh in the early 1990s. Oil, coal and hydro was the primary contributor to electricity generation as one of the priorities of Indonesia's energy policy plan KUBE 1980 – 1990. Since the 1990s, the revision of the energy plan KUBE facilitated the exploration of new energy resources such as natural gas, geothermal, hydropower, wind and solar (Figure 16). In 2020, Indonesia can produce 293 TWh, almost an eight-fold increase in 30 years. The following figure shows the improvement in Indonesia's capability to produce electricity.

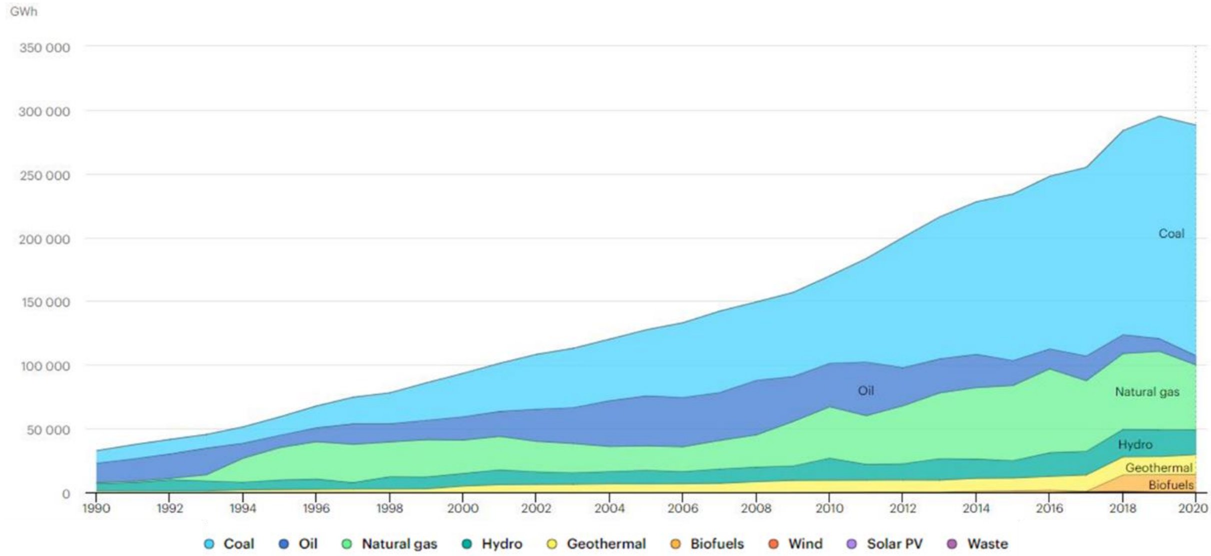

Figure 16 Total Electricity generation 1990 -2020 (IEA, 2022)

From 1990 – 1998

At the end of the national development plan, Repelita V (1989 – 1994), more than 13 GW power plants (excluding the captive power) consisting of 13 GW power plants owned by PLN and 96 MW power plants owned by the private sector were operated. At that time, Indonesia had nearly 17,000 km of transmission lines and 847 units of substations. Also, Indonesia had 260,000 km distribution lines and 124,000 units of distribution substation. During the next national development plan, Repelita VI (1994 – 1998), power plant, transmission and distribution were expanded significantly. The power generation capacity reached 21 GW at the end of 1998. Meanwhile, transmission and distribution lines were increased to 23,000 lines and 450,000 lines, respectively (MEMR, 2007).

From 1998 – 2003

The growth of the electricity sector in Indonesia faced a setback after the financial crisis in 1998. According to MEMR (2007), PLN's power plant reached 21 GW at the end of 2003, which only increased by 1 GW compared to the capacity at the end of Repelita VI (1998). Meanwhile, The transmission and distribution lines were not expanded significantly. The transmission lines only increased by 4,000 km, and distribution lines developed by 26,000 km at the end of 2003.

From 2003- Present

In the post-financial crisis, Indonesia's electricity sector developed significantly after the government announced the national energy plan (KEN) in 2003. At the end of 2020, Indonesia produced 72 GW. PLN contributed 43 GW, more than two times greater than PLN's contribution in 2003. Meanwhile, the private sector power contributed 29 GW in 2020, almost seven times greater than its contribution in 2003 (3GW). Moreover, transmission and distribution infrastructure expanded massively, with the transmission lines reaching 62,000 km and 2,245 substations. The distribution line reached 1,006,000 km with 527,000 substations (MEMR, 2021b).

Future reserve margin

According to PLN (2021), the new power plant from the previous government project (35.000 MW project) will start to operate, leading to oversupply in the Java – Bali and Sumatera system. Currently, PLN is estimating 40-60% reserve margin in the Java-Bali grid and a 30-56% margin in Sumatera (figure 17). The oversupply condition is also forecasted to continue until 2030 due to decreased future demand because of the COVID-19 pandemic (Hamdi & Adhiguna, 2021). As stated in the following statement by an official staff from PLN, the condition of oversupply has become a barrier for PLN to develop renewable energy, especially in the Java-Bali system.

> *"PLN must be careful in implementing rooftop PV because of oversupply and cash flow from PLN where electricity rates do not increase, and subsidies are continuously reduced."* (Interviewee #11, 2022)

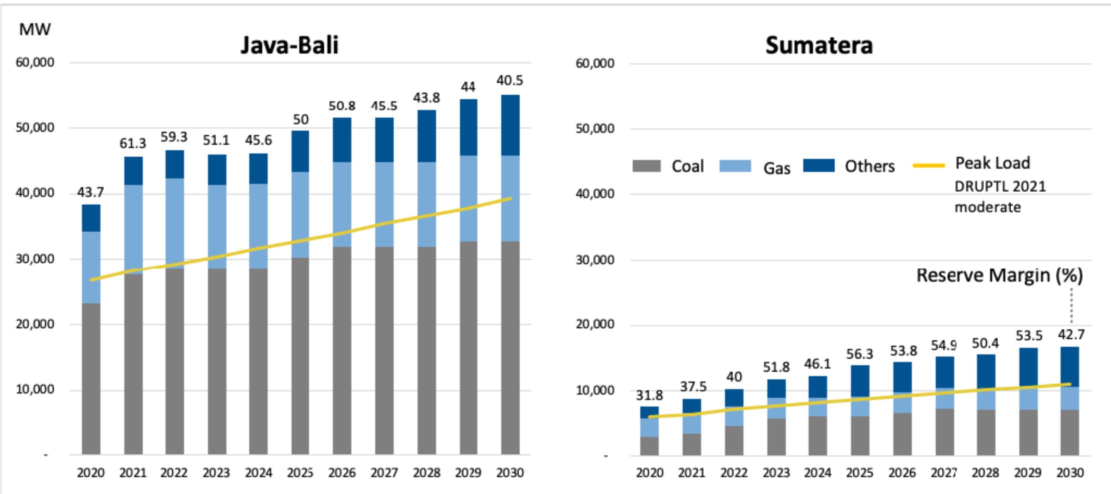

Figure 17 PLN grid over-supplied (Hamdi & Adhiguna, 2021, p. 12).

5.2.4. User and market preferences: Public awareness

Climate change at the landscape level has continuously influenced user awareness of sustainability issues. According to one official government, public awareness of the environmental issue has progressively increased. More people currently have already concerned and interested in installing PV (Interviewee #15, 2022). In addition, the growth in engagement and awareness of sustainability in Indonesia is 53% which means more people are aware of the environment (WWF and The Economist Intelligence Unit, 2021). Subsequently, several users consider the rooftop PV a prestige item in line with the public awareness of sustainability. The user representative mentioned:

> *"Another factor is the prestige or lifestyle factor where we can show others that we use rooftop PV."* (Interviewee #15, 2022)

Furthermore, the evaluation of company performance based on the initiative in environmental, social, and governance issues, has increasingly been recognised and has a higher value in the stock market (Aditya, 2022). In Indonesia Stock Exchange (IDX), ESG investment, an investment activity that considers financial metrics and ESG factors as the basis of decision-making, is increasingly growing (IDX, 2022). As mentioned previously, investors in Asia-Pacific are reported moderately or significantly increasing investment in ESG (MSCI, 2021). Investors usually use the ESG rating to measure the accomplishment of a company in the ESG issues. Moreover, many companies, including coal companies, are willing to involve and have renewable energy portfolios. New trends in companies with a renewable energy portfolio have become common in Indonesia (Interviewee #9, 2022).

The International pressure from the landscape level on the industrial sector has influenced companies in Indonesia to adopt rooftop PV. In particular, for multinational companies, the headquarters have encouraged rooftop PV as one strategy to increase the ESG score (Interviewee #4, 2022). Moreover, the consumer's behaviour in searching for a green product is increasingly by 71% (WWF and The Economist Intelligence Unit, 2021). Therefore, the rising industrial participation due to international and market pressures in adopting rooftop PV is a supportive factor for the diffusion.

5.3 MLP Analysis Conclusion

MLP framework is used in this thesis to analyse the rooftop PV niche development in Indonesia from two levels of perspective: socio-technical landscape and socio-technical regime level. At the socio-technical landscape level, six factors were identified influencing the rooftop PV development. Those six factors are rural development and electrification, the 1997-1998 economic crisis, energy security, climate change, international and market pressure, and the COVID-19 pandemic. First, during the 1990s, the problem of low electrification in rural areas (51.83% in 1993) motivated multiple non-governmental at the niche level (R&S Renewable Energy company, DGIS, and World Bank) and governmental organisations at the regime level (including the President) to develop solar home systems (using rooftop PV as the standard design model). However, the use of rooftop PV as a rural electrification solution was hampered by the financial crisis in 1997-1998. Due to the impact on the financial sector (GDP collapse, high-interest rates, high inflation, rupiah devaluation, and a significant increase in the price of

PV module) and the political sector (President's resignation and suspension of all national development plans) created uncertainty in the market and demoralised several actors such as banks (unable to provide loan) and users (unwilling to use loan). The third factor at the landscape level is energy security. Since 2004, the issue of energy security in Indonesia has emerged mainly after Indonesia became a net importer of oil (contributing to 33% of the energy supply). The issue of energy security and dependence on oil imports from other countries put tension on the government regime to develop renewable energy. To eliminate this problem, the government, through KEN, announced a target to produce 17% of its energy supply from renewable energy sources like solar energy by 2025. In addition, the government also introduced the feed-in-tariff scheme to encourage private and public participation in developing renewable energy (i.e., rooftop PV) in Indonesia. The next landscape factor is climate change. In response to the Paris agreement in 2015, the government accelerated renewable energy development by revising the target from 17% to 23% by 2025. Another factor at the landscape level is pressure from the market and international (e.g., from headquarters, investors and consumers). Pressure from the market forces the industrial sectors to increase the company's SDG score, where the use of rooftop PV is one of the strategies to improve sustainability. The last factor at the landscape level is the covid-19 pandemic in 2020-2022. The pandemic disrupts the PV supply chain (longer shipping time and higher price) and increases the market's uncertainty.

The six factors at the landscape level led to some changes in the regime level. First, in the 1990s, the government announced new development policies for solar home systems (mainly rooftop PV) to increase the electricity rate in rural areas. Policies such as financial incentives and installation programs were outlined in the national development plan, Repelita V and Repelita VI. Moreover, the low electrification rate in Indonesia forced the government to implement a policy to expand the electricity system, which resulted in a significant increase in electricity supply, transmission and distribution lines. Secondly, the 1997-1998 financial crisis had an impact on the regime level by changing the regime actors (change of President) and policies (cancellation of national development policies). Thirdly, the energy security issue since 2004 has encouraged the government to develop renewable energy. At that time, the government set a renewable energy goal of 17% share in the energy mix by 2025. Moreover, the government also introduced feed-in-tariff schemes to support the development of renewable energy, such as rooftop PV. The factor of climate change at the landscape level, especially after the Paris Agreement 2015, made the government accelerate the renewable energy development plan. The government revised the renewable energy target from 17% to 23% by 2025

CHAPTER 6 – STRATEGIC NICHE MANAGEMENT ANALYSIS

This chapter aims to analyse the niche strategy applied in rooftop PV development in Indonesia. The analysis uses the concepts of Strategic Niche Management, which consist of shielding, nurturing and empowerment. The data used in this chapter are based on the information collected in a semi-structured interview with various stakeholders. At the end of the chapter, the opportunities and barriers in the niche process are drawn based on the analysis.

6.1 Shielding

This section discusses two shielding strategies, active shielding and passive shielding.

6.1.1. Active shielding

The active shielding for rooftop PV niche development in Indonesia has been performed by the government and non-governmental organisations since the pilot project of rooftop PV in the 1990s. In response to the issue of rural development and electrification, the government agency collaborated with private companies (R&S, recently known as shell solar energy) and the Netherlands DGIS to organise a solar home system project for rural development in Sukatani villages in West Java. Following the Sukatani project, the government announced financial incentives to install 3250 solar systems included in the national development plan Repelita V in 1991-1992. Subsequently, the government announced a "Fifty Mega Watt peak Photovoltaic Rural Electrification " project to install 1 million solar systems in several places, such as households and rural clinics (de Quay, 1994). In addition, a non-governmental organisation like the world bank provided a loan program for 200,000 units of the PV system (Miller & Hope, 2000). These three active shielding strategies are encouraged by the rural development and electrification factor at the landscape factor.

Furthermore, in response to the energy security issue since 2004, the government applied active shielding for rooftop PV in 2013 by introducing the feed-in-tariff (FiT) scheme. The FiT scheme provides a financial incentive to the user as a shielding strategy to protect and encourage rooftop PV diffusion. However, due to the impact of the FiT system on PLN revenue performances, the government replaced the FiT scheme with the metering scheme. The metering scheme was implemented in 2018, with exported electricity value still 65% (Hamdi & IEEFA, 2019). In 2020, through MEMR Regulation No.26 of 2021, the government increased the export-import metering multiplier from 65% to 100%. In addition, the accumulation system for excess available power also rises from three to six months (PwC Indonesia, 2021).

Another shielding strategy is conducted through a collaboration between government and non-governmental organisations. Since early 2022, the government has collaborated with UNDP to organise a new program called MTRE3 to boost the diffusion of rooftop PV. This program aims to support the sustainable development of Indonesia in response to the climate change issue. Through the MTRE3 project, the government directly provides and offers incentives to the potential user of rooftop PV. The allocation fund is called Sustainable Energy Fund (SEF) (United Nations Development Program, 2022).

Another active shielding the government applies is the focus group discussion (FGD) with related stakeholders such as user representatives, PLN, developers, etc. According to Interviewee #13 (2022), the government actively communicate, meets and conducts FGD with other stakeholders during the policy-making process. The FGD aims to gather information and opinions from the rooftop PV stakeholders.

Moreover, one state-owned energy company, Pertamina, carry out an active shielding through the company's sustainable program. Pertamina has conducted a new concept called the Green Energy Station (GES) program to encourage the company's transition energy plan. GES program aims to create more sustainable environments for the customer by installing rooftop PV in petrol stations, operational areas, offices, and supporting facilities. Currently, Pertamina aims to install rooftop PV at 5,000 gas stations (Pertamina, 2021).

Another active shielding was the bulk buying activities organised by the early adopter of the smart-meter system of rooftop PV. As mentioned by the user representative: :

> *"6 months after the successful operation of the metering system pilot project, many people came to me asking for rooftop PV installation. Due to high demand, we organised and bought components such as panels and inverters collectively and in bulk to lower prices"* (Interviewee #15, 2022)

The collective and bulk buying activities are considered active shielding strategies because they provide protection space for rooftop PV in the early adoption.

6.1.2. Passive shielding

Like active shielding, the passive shielding for rooftop PV diffusion in Indonesia is applied by the government and non-government organisations. To protect the niche development, the ministry announced a policy to install rooftop PV in every government building, such as offices, schools, hospitals, etc. Moreover, the central government also issued a letter to the local government to use rooftop PV in local government-owned buildings. The policy to install rooftop PV in government buildings provides a protected space for rooftop PV to be used without intervention from outside factors such as the current regime. Moreover, besides the passive shielding strategy, the use of rooftop PV in government buildings is expected to become an example for the public and a marketing tool for the broader community (Interviewee #12, 2022).

Non-governmental organisations such as associations undertake the following passive shielding to support rooftop PV development. For instance, the association of Indonesia solar manufacturers (APAMSI) is an organisation where local manufacturers collaborate and transfer knowledge to make solar PV more efficient, affordable and accessible (APAMSI, 2021). Another passive shielding is managed by the Indonesia association of rooftop solar users (PPLSA). PPLSA is an open member-based organisation and communication forum enabling rooftop users to share information about rooftop PV with wider communities. The Indonesia solar energy association (AESI) develop entrepreneurship and human resources in the PV industry through 'Solarpreneur' initiatives. Institution for essential services forum (IESR) is another NGO that encourages energy transition through various programs such as research, policy advocacy, public campaigns, etc. In addition, IESR and MEMR organised a 'Solar Summit' event in 2022 (ISS, 2022). The aforementioned collective movements from NGOs supporting the rooftop PV diffusion are considered passive shielding strategies from the bottom-up organisation. The following table summarises all identified shielding strategies.

Table 11. Summary of shielding strategy

Dimension	Active shielding	Passive shielding
Markets	Loan from World Bank, Sustainable Energy Fund (SEF)	A national movement for one million rooftop solar systems 2017
Infrastructure	Demonstration project and rooftop PV adoption in all gas station	
Public policies	Financial incentive, focus group discussion with related stakeholders and feed-in tariffs	Installation in the government building
Industry structure	Bulk buying activities	Collective activities by NGOs

6.2 Nurturing

6.2.1. Articulation and shaping expectations

According to Kamp & Vanheule (2015), the expectation is evaluated for the expectation of the niche actor (internal expectation) and the actor's expectation outside the niche (external expectation). Both expectations are discussed in this section. In addition, factors shaping expectations from landscape and regime levels are also discussed.

a. Internal expectation

This thesis presents expectations from niche actors such as developers, EPC (installer), suppliers, NGOs, and users.

Developer companies

Due to the high potential of solar energy in Indonesia, significant market demand and a growing number of players in the market, two rooftop PV developers are optimistic about rooftop PV development in Indonesia (Interviewee #1, 2022; Interviewee #8, 2022). One developer argued that with the increasing pressure from the international market on several industrial companies, the awareness of companies to install rooftop PV would increase, leading to higher demand (Interviewee #1, 2022). Moreover, another developer argued that rooftop PV can be a shortcut strategy for the government to achieve the renewable energy target in the energy mix in 2025 (Interviewee #8, 2022).

Despite the high expectation, the two developers mentioned that the rooftop PV development is facing several challenges. According to Interviewee #1 (2022), the challenges are related to permit approval from PLN, capacity limitation by PLN, and 60% local content regulation. Regarding the permits, the authorisation from PLN should be issued within five business days after the application (Hamdi & IEEFA, 2019). However, one respondent experienced a longer time (five months) for approval and possible rejection for several projects. Thus, the longer time and uncertainty of receiving approval are argued as a barrier for niche actors to develop rooftop PV (Interviewee #1, 2022). Another challenge faced by the developer is related to the capacity limitation imposed by PLN. Currently, the rooftop PV capacity is limited to 10-15% of the maximum installed capacity of PLN, thereby reducing the economic benefit of rooftop PV. Due to the limited installation and low electricity price, one respondent said that it is currently difficult for developers to make a profit under these conditions. To eliminate risks and improve the profitability of business activity, developers expect incentives from the government for business actors (Interviewee #8, 2022). Another problem raised by the respondent is related to the regulation on 60% local content (TKDN). Interviewee #1 (2022) noted that 60% TKDN makes the electricity cost more expensive than the current electricity price, especially for larger projects. Currently, developers face the dilemma of choosing between a low price without following TKDN regulations or an expensive cost that meets TKDN regulations. Developers currently face this challenge when participating in tenders of big projects (Interviewee #1, 2022).

Engineering, Procurement and Construction (EPC or installer) company

EPC companies have high expectations for rooftop PV niche development. Interviewee #2 (2022) stated that rooftop PV will be widely adopted in Indonesia, primarily when the surrounding environment, such as regulations, politics, technology and prices, are supported. Furthermore, EPC companies believe faster adoption will occur in the industrial sector due to the significant capital, stable loads, and larger roof area. However, issues such as installation permits from PLN and price war between solar market players are challenges EPC company faces. According to one business developer at the EPC company, the main obstacle for rooftop PV diffusion is the permit approval from PLN. Currently, PLN is reluctant to issue permits because the rooftop PV adoption will reduce the companies' revenue. Thus, the permit issue is the most critical problem for the EPC companies (Interviewee #2, 2022).

Technology suppliers

Technology suppliers' expectations in Indonesia are considerably high due to the potential of solar energy and government policy. As mentioned by one business developer in a manufacturer company:

"... It can be concluded that we are still reaching a small capacity from such vast potential. With this considerable gap, my expectations are very high. If Indonesia can bridge this gap, we should be able to achieve the target. I'm still very optimistic in this field." (Interviewee #5, 2022)

Although most of the rooftop PV is an on-grid system, the off-grid system using storage systems are expected to grow. The representative of the manufacturer association stated:

".... Last year, many clients used rooftop solar panels for savings. Currently, they want to use storage to not depend on PLN." (Interviewee #14, 2022)

Financial institutions

Financial institutions view rooftop PV as the future market for investment. Considering the high government's commitment to developing renewable energy, the potential of solar energy, global pressure on sustainability and the growing demand, financial institutions believe that rooftop PV will progressively develop. Moreover, in recent days, more companies like coal companies have been involved in the renewable energy industry (Interviewee #9, 2022).

However, financial institutions and banks are still reluctant to invest in rooftop PV because the investment risk is very high due to the high cost and long-term repayment period. Especially in the residential sector, rooftop PV will be challenging to become project finance because the capital is small, and the number of clients is significant. Moreover, for financial institutions and banks, securing guarantees is difficult if the rooftop PV project fails. Unlike other technology or projects, the takeover is impracticable due to the impossibility of making roof or rooftop PV a guarantee. Problems as previously mentioned, are faced by financial institutions in providing financial support (Interviewee #9, 2022).

NGOs

After the announcement of MEMR Regulation No. 26 of 2021, the NGOs were highly optimistic that rooftop PV would be widely implemented. However, due to the restriction by PLN and uncertainty in the law implementation, NGOs assess that the rooftop PV development is experiencing a setback. One researcher in NGOs explained:

> *"Last year, I was optimistic because there were revisions on the regulation. But if you look at this year, I think it's slowing down again and experiencing a setback. Because of that, people are discouraged. And, if you read the news, they might say they want to revise the 100% export-import multiplier again, so I don't know what it means. The policy is difficult to express in black and white, which regulation is correct. Similarly, although the regulatory changes are good in another year, the new regulations are not implemented."* (Interviewee #7, 2022)

Despite several issues, NGOs remain optimistic that rooftop PV will continue to grow, especially in the industrial sector (Interviewee #7, 2022).

Users

According to one member of the user association, user expectations are highly correlated with price. Due to the relatively high price of rooftop PV compared to the current electricity tariffs, the public expects an increase in subsidies. For potential users from the upper, middle-class, or even younger generations who are already aware of environmental issues and want to use rooftop PV, the cost of using rooftop PV is considered very expensive compared to daily necessities. Therefore, an increase in subsidies is expected to support the potential users and decrease the payback period (Interviewee #15, 2022).

b. External expectation

The present section presents expectations from actors outside the niche, such as electricity operators (PLN), central government, and provincial government.

Electricity operator: PLN

Although rooftop PV is considered a disruptive technology for PLN revenue and business, the division of strategic business development sees the rooftop power plant as a future business opportunity for the company. Therefore, in 2020, PLN launched a service called ‘Rooftop PV Total Solution’ to provide rooftop PV services to meet customer needs. One official member of strategic business development in PLN stated:

> *“With the 'Rooftop PV Total Solution' service, we want to deliver rooftop PV services to meet the needs of PLN customers for rooftop PV but without disrupting PLN's business. We will continue to develop this rooftop PV business with a scheme that will not interfere with PLN's business.”* (Interviewee #10, 2022)

The above statements indicate a growing interest within PLN to promote rooftop PV as a future business model. However, the statements also express a reluctance to embrace large-scale rooftop PV adoption as it would disrupt PLN’s business. Furthermore, public statements made by PLN officials in 2018 emphasised that the adoption of rooftop PV should not be prioritised for people living in Java-Bali, as the electricity generation is oversupplied. The PLN official also said that distributed solar panels should be adopted in areas outside Java, where many locations still experience power shortages

Central Government

Indonesia has a sustainable goal of 23% renewable energy in the energy mix by 2025. In 2021, Indonesia could only reach 12.16% renewable energy (MEMR, 2021a). Although rooftop PV is not included in the 10-year national electricity development plan issued by PLN, the central government considers PV a strategy to achieve the sustainability target. As one official deputy director of MEMRmentioned:

"…The government, in this case, actually added this rooftop PV program outside of the RUPTL. To make rooftop PV as a backup to achieve the RE target in 2025 if RE programs iin the the RUPTL fail to be implemented." (Interviewee #12, 2022)

Moreover, the central government's expectation of rooftop PV correlates to Indonesia's energy security. As explained in the MLP analysis chapter, the government of Indonesia currently encourages renewable energy development such as rooftop PV to ensure energy security and independence (Interviewee #12, 2022).

Provincial Government

One official provincial government of West Java expect that the rooftop PV will be massively deployed on a large scale, especially given the high energy demand within the province. However, the official of the west java government also mentioned that the development is currently limited due to the limited capability and reliability of the electrical systems in West Java in response to the solar energy intermittency. The rooftop PV is expected to be developed by combining with other renewable resource technologies such as water, hydropower, geothermal, and biomass-based power plan (Interviewee #6, 2022).

c. Factor shaping expectation

This segment discusses factors that shape the expectation of various stakeholders described earlier. Two factors are analysed: (1) exogenous factor and (2) endogenous factor.

Exogenous Factor

Exogenous factors refer to factors influencing actors' expectations from outside the niche. These factors include factors at the socio-technical landscape level (discussed in chapter 5), such as rural development and electrification, financial crisis, energy security, climate change, market pressure, and covid-19. In the early stage of development in 1990, the rooftop PV was expected to become a solution for rural development and electrification through the solar home system project (de Quay, 1994). In addition, World Bank's objective in providing loans for the solar home system was to support rural development and electrification at that time (World Bank, 2001). However, the actor's expectations declined due to the financial crisis in 1997. According to World Bank (2001), the implementation of solar home systems was slow during the crisis. High inflation, high-interest rates, GDP collapse and uncertainty in the future demotivated several actors, such as installation providers and commercial banks. Only one installation provider conducted the project despite 5-6 qualified providers. In addition, the commercial bank provided only a minimal loan due to the financial crisis (World Bank, 2001). In the post-financial crisis, the actor's expectations increased due to the energy security issue (after Indonesia became a net oil importer in 2004) and climate change (Paris agreement in 2015). According to the official government, rooftop PV is expected to continuously develop and become a strategy to solve the energy security issues and achieve the climate change goal in Indonesia (Interviewee #12, 2022). Moreover, the government's introduction of renewable energy targets and feed-in-tariff schemes boost the expectation of actors (Interviewee #5, 2022; Interviewee #9, 2022). The pressure from the international market that increased the market demand for rooftop PV also raised positive optimism on the rooftop PV niche development (Interviewee #1, 2022; Interviewee #8, 2022).

Furthermore, several exogenous factors are identified at the socio-technical regime level. Factors such as regulatory change and PLN policies are found to shape the expectation of the actors. Regarding the regulatory changes, the announcement of the MEMR regulation in 2021, which underlines the revision of the metering scheme tariff from 65% to 100%, raised the expectation of business actors (Interviewee #5, 2022; Interviewee #9, 2022). Moreover, the available financial incentives and subsidies expected by users and developers to increase the economic benefit of rooftop PV also shape the expectations (Interviewee #15, 2022; Interviewee #8, 2022). However, PLN internal policies regarding capacity limitation and permit approval were mentioned by several business actors as obstacles and explained to have a negative influence (Interviewee #1, 2022; Interviewee #2, 2022; Interviewee #7, 2022; Interviewee #8, 2022).

Endogenous Factor

In contrast to the exogenous factor, the endogenous factor influences the actor’s expectations from inside the niche. The first endogenous factors was the innovation of the solar home system organised by R&S company in the 1990. The success of the solar home system innovation in Sukatani village, where the solar potential was lower than average, inspired the government to utilise the rooftop PV to improve the rural electrification rate. According to Lysen (1994), the President became enthusiastic about the success of the Sukatani project and started a new Presidential assistance project called the solar home system for rural areas. In this project, the government provided financial incentives as outlined in Repelita V. The success of this project (3250 solar panels installed in fourteen provinces) in 1992 raised the expectation within the government. The government announced the new initiative, namely “Fifty Mega Wattpeak Photovoltaic Rural Electrification Program, to accelerate the PV diffusion in rural areas. This new project also influenced non-governmental organisations such as World Bank to participate in the initiative. In this initiative, World Bank participated by providing funding to potential users (de Quay, 1994).

Another endogenous factor influencing rooftop PV development is the increased number of actors involved in rooftop PV. According to Interviewee #9 (2022), companies engaged in rooftop PV industries are growing. Various companies, including new start-ups, venture capital, local manufacturing companies and coal companies that want to diversify their business portfolio, actively participate in rooftop PV niche development. Moreover, the participation of NGOs such as IESR, APAMSI and AESI in providing knowledge sharing is considered a positive influence on the actor’s expectation. Therefore, the growing number of actors and multiple activities organised by niche actors raise the positive expectation of PV (Interviewee #9, 2022)

6.2.2. Social network formation

a. Composition

The composition of social network formation is identified according to semi-structured interviews and desk research. The composition is described and classified based on two pattern times: (1) From 1990 -2003, which mainly focused on the innovation of solar home systems in rural areas, and (2) From 2003 – Present, which mainly focused on rooftop PV diffusion in various sectors including industry and households. Generally, the social network formation of solar PV development in Indonesia is summarised as follows.

<u>During the introduction of rooftop PV in the 1980s-2000</u>

The solar home system's innovation was started at the end of 1980 by the collaboration of three organisations: R&S company, Dutch governmental agencies (DGIS) and Indonesia agency (BPPT). R&S company, as the principal innovator, had a significant role in conducting research, developing and conducting the demonstration project of solar home systems in rural areas. A Dutch government agency (DGIS) and an Indonesian government agency (BPPT) were responsible for assessing and applying technology, including the policy and market assessment. The assessment was implemented using the data loggers and frequent surveys of technical and social aspects (Reinders & Sudradjat, 1999). After the demonstration project, on January 24, 1991, a joint venture company called PT. R&S Rekadaya Energy Surya was founded. This joint venture was 20 per cent owned by Indonesia's state-owned installation firm (WIKA) and 80% per cent owned by SEPL (Solar Electric Power and Lighting, the Netherlands). The SEPL consisted of the Shell group of companies and Philips lighting cooperation. PT. R&S Rekadaya Energy was the primary PV provider that conducted activities such as marketing, assembling, production, installation and maintenance of rooftop PV systems (de Quay, 1994).

Moreover, various technology suppliers were also involved in the rooftop PV niche development. R&S Netherlands (Shell group) supplied the PV modules and regulator instruments. Another company was a local subsidiary of a Japanese organisation, namely PT. Yuasa contributed to providing almost 9,000 batteries and 60,000 litres of battery acids. Philip lighting cooperation provided tube lamps for the solar home system project. Meanwhile, local manufacturers produced and supplied cables and inverters (de Quay, 1994). The success of the demonstration project attracted government and non-governmental organisations. The government (President, MEMR, and BAKOREN) supported the innovation by providing a supportive approach and financial incentives (de Quay, 1994). Meanwhile, the World Bank encouraged rural development in Indonesia by providing financial support. Lastly, people live in rural areas as the users were responsible for operating and maintaining the rooftop PV system. The following table summarises the composition of social network formation during the innovation of the solar home system from 1990 – 2003.

Table 12 Social network formation during 1990 - 2003

No	Stakeholder	Organisation Name
1	International donors	World Bank
2	Central government	President
		MEMR
		BAKOREN
3	Government Agency	Indonesian agency for assessment and application of technology (BPPT)
4	PV developers and installer	PT. R&S Rekadaya Energi
5	PV Modules supplier	Private company – R&S Netherlands (Shell group)
6	Battery supplier	Private company: PT. Yuasa
7	Regulator supplier	Private company – R&S Netherlands (Shell group)
8	Tube Lamps supplier	Private company – Philips lighting cooperation
9	Inverter supplier	Local company – PT. R&S Rekadaya Energi
10	Cable and PCB supplier	Local company
11	Financial institutions	Bank
12	International agencies	DGIS
13	Users	People live in rural areas
14	Investor	WIKA, Shell groups and Philips cooperation

From the 2000s – the 2020s

Currently, the establishment of the rooftop PV social network in Indonesia involves a wide range of stakeholders, such as international institutions, central and provincial governments, electricity operators, rooftop PV developers, EPC companies, financial institutions, and consultancy firms, and users of rooftop PV. In this report, detailed descriptions of each stakeholder are provided in the stakeholder analysis (chapter 4.3). The following table presents the list and composition of rooftop PV social networks in Indonesia.

Table 13. Social network composition

No	Stakeholder	Organisation Name
1	International donors	United Nations
2	Central government	MEMR
		Ministry of State-Owned Enterprise
		Ministry of Industry
		Ministry of Finance
3	Provincial government	e.g., West java local government
4	House of representative	Commission VII
5	Electricity operator	PLN and private operator company
		Private company
6	Rooftop PV developer	Private company
7	Engineering, Procurement and Construction (EPC)	Private company
8	Financial institutions	Bank

		Investor
		State-owned company
9	Consultancy firms	Mechanical and electrical consultant
10	NGO	Associations and think-tank organisations
11	Research institute	University
		Governmental agencies such as BRIN
12	Users	Rooftop PV user associations

b. Alignment

The alignment between stakeholders was identified during 1990 – 2003 (innovation of solar home systems in rural areas). The government launched the national movement called "Fifty Mega Watt Peak (50 MWp) Photovoltaic Rural Electrification" that aimed to electrify one million households in ten years. The initiative was aimed to increase the cooperation of private sectors in rural electrification (Dasuki & Djamin, 1994). The initiative successfully encouraged multiple non-governmental organisations such as the world bank and private companies.

In September 2017, a National Movement for One Million Rooftop Solar System (*Gerakan Nasional Sejuta Surya Atap*, abbreviated as GNSSA) was launched to support the National Energy Policy (KEN) in achieving a 23% renewable energy target by 2025. The initiative was supported by many stakeholders, including the MEMR, the Ministry of Industry of Indonesia, the Indonesian Solar Energy Association (AESI), the Indonesia Association of Solar Manufacturers (APAMSI), and the Indonesian Association of Rooftop Solar Users (PPLSA), among others. The movement aimed to accelerate the rooftop PV diffusion by realising minimal 1GWp rooftop solar rooftop and implementing rooftop installation in public facilities, government offices, commercial buildings and industries before 2020 (MEMR, 2017a). The movement was able to increase the adoption of rooftop PV. Within three years after the declaration, the rooftop PV users increased from 268 users in 2017 to 2300 in 2020, with a total capacity of 11,5 MW. Although the GNSSA initiative failed to achieve the original goals, the GNSSA was able to create collaboration among related stakeholders (Saputra, 2020). The GNSSA initiative currently continues to support renewable energy development (Aditya, 2022).

Although the role and alignment between stakeholders have been clearly defined (see chapter 4.3), the different actors' interests pose challenges to collaboration. For example, during the policy-making process, the government conducts FGD to gather information and wishes from each stakeholder. As noted in the following statement, the government faces challenges in policy-making due to the different interests of each stakeholder.

> *"There are challenges in collaboration with various stakeholders. During the focus group discussions, every organisation conveys its ideal desire. For example, from the perspective of PLN and other electricity operators, they prefer to prioritise private sectors. The association and*

the community prioritise the community or the industry. In the end, the decision is made based on the hearing and instruction from the Minister." (Interviewee #13, 2022)

The second challenge is the alignment between the rooftop PV company with PLN regarding the cooperation in permit approval from PLN. According to the rules, before installing, a rooftop PV company must apply for a permit to PLN. Subsequently, PLN has to answer within a week. However, the uncertainty of the response by PLN becomes an issue in this alignment (Interviewee #1, 2022).

6.2.3. Learning Process

This section analyses seven aspects of the learning process in rooftop PV niche development, namely technical and infrastructure development, policy and regulation, user context development, industry development, environmental and social impact, energy potential, and business model.

a. Technical and infrastructure development

The learning process in terms of technical aspects is discussed in two parts. The first part is an analysis of the learning process during the introduction of rooftop PV in the 1990s. Subsequently, the second part discusses the learning process in the current situation.

During the introduction of rooftop PV in the 1980s-2000

According to de Quay (1994), rooftop PV in the solar home system was developed in five phases: (1) laboratory phase, (2) prototype phase, (3) demonstration phase, (4) diffusion phase, and (5) acceptance phase. During the laboratory phase, the basic concept of the solar home system was designed and developed. In addition, market studies were also performed to understand the need of the people. The laboratory phases ended after the concept was developed in 1987 and continued to the prototype phase. In the prototype phase, a tried-out under 'normal' conditions was applied in 1989. PV modules used in this phase were produced by R&S Company in France and Netherlands. The two first development phase was thoroughly conducted by the R&S Company, the principal innovator of the solar home system in Indonesia (de Quay, 1994).

In the demonstration phase, the prototype was demonstrated in Sukatani village in 1989. The demonstration was focused on analysing the technical feasibility of the solar home system concept. The demonstration project was necessary for the R&S company to evaluate and monitor the solar home system design in the actual situation (de Quay, 1994). During the demonstration, some technical problems were found, mainly issues with the charge controller and lights. Moreover, the incompatibility of the battery system in the prototype and users' consumption was learned during this phase. Based on the monitoring outcome by BPPT, the use of the 100 Ah (Ampere hour) battery was overcapacity compared to the electricity consumption of users. BBPT suggested to R&S Company to using 70 Ah batteries as replacement of 100 Ah batteries (Nieuwenhout et al., 2000). These technical problems of charging controller and lights and also overcapacity of the batteries became the lesson learned during the pilot project in Sukatani village. Moreover, after the installation, the users (local villagers) were trained and received an instruction sheet about the maintenance and use of the system (Reinders & Sudradjat, 1999). This shows that the learning process in terms of technical development and infrastructure was actively carried out by a private company, R&S, and a governmental agency, BPPT. The observation of the problems, users' needs, and the technology's adjustment present the learning process in this phase. Moreover, the knowledge transfer from the private company to the local people occurred through the installation process, training and instruction sheet.

The learning process in terms of technical development is also identified in the diffusion phase. During the Banpres project, the manufacturing company found the same problem in the charging controller. The local technician found that the charging controller restricted the lighting duration of solar energy. Due to a lack of alternatives, the local technicians decided to bypass the controller (Nieuwenhout et al., 2000). In addition, in terms of the battery, it was found that the locally produced batteries could not match the characteristics specified by the manufacturers (de Quay, 1994). Lastly, the village cooperative unit (KUD) was responsible for the system's maintenance process and technical problems. The private companies provided the KUD members' training session (Nieuwenhout et al., 2000). Technical problem solving by local technician and training sessions for business stakeholders (in this case, KUD) shows some learning processes during the diffusions phase.

To sum up, the learning process in the early stage of rooftop PV that has been analysed took several forms of learning. Those forms are the problem and solution discovery, the user needs identification, technology adjustment to fit the user's needs, and transfer knowledge to the local villagers and village cooperative unites (KUD). Moreover, the R&S company, as the innovator, distinguished themselves from the competitors at that time through the demonstration project in Sukatani and Lebak.

<u>From the 2000s – the 2020s</u>

Although most necessary technology for rooftop PV installation in Indonesia was imported from China, several local stakeholders still conduct the learning process regarding technical aspects. For instance, the state-owned energy company, Pertamina, arrange an in-house research and development (R&D) division for solar PV development. Pertamina focuses on developing a monitoring system and prediction system of the intensity of solar energy. This system is used to predict how much electricity will be produced in the short or long term. For PV development, Pertamina has invested a considerable effort in the R&D sector (Interviewee #4, 2022). Another state-owned company arranging an in-house R&D division is the incumbent company, PLN. The R&D division is responsible for updating and following the new development in the renewable energy sector. Many internal seminars with foreign speakers such as global universities, practitioners, experts or companies are organised to improve the company's internal knowledge regarding PV development (Interviewee #11, 2022).

Furthermore, the private sector also participates in various learning activities regarding the technicality of rooftop PV. During the interview, many respondents mentioned exhibitions, seminars, workshops, and conferences are common learning activities in the private sector. One exhibition, namely Solartech, was an exhibition where many international and local suppliers gathered (Interviewee #14, 2022). This exhibition provides an opportunity for the private sector to learn and evaluate the products compared to the competitors (Solartech Indonesia, 2022). Moreover, the learning process was also conducted by the government through collaboration with the foreign government or agency. As mentioned by Interviewee #7 (2022), the government of Indonesia collaborate with foreign governments, such as the Denmark government, to develop rooftop PV technology. The government also conducted seminar and workshop regarding the collaboration results.

> "*…. the government often organised workshops. For instance, workshop regarding the result of collaboration with the Danish or Norwegian government on rooftop PV technology*." (Interviewee #7, 2022)

To sum up, the learning process related to the technical aspect is currently taking various forms of activities, such as research and development, seminar, workshop, exhibition, and conferences.

b. Policies and regulations

<u>During the introduction of rooftop PV in the 1980s-2000</u>

After learning that the pilot project in Sukatani village was successful, Indonesia's president, Soeharto, was interested in solar PV technologies and wanted to develop the technology as a solution for rural electrification. Following the success of the Sukatani project, the Government announced the acceleration program of solar PV diffusion, namely the "Banpres (*Bantuan Presiden* or President-assisted) Project" in the rural home system through the national development plan 'Repelita V'. The government provided a financial incentive to develop a solar home system in rural areas through this policy. Subsequently, in the next national development plan, 'Repelita VI', the new project called "Fifty Mega Watt peak Photovoltaic Rural Electrification" was announced. The objective of the project was to install PV in 1 million units in rural areas (de Quay, 1994). However, the project was not continued due to the financial crisis and the change in government.

This case shows that during the introduction of rooftop PV, the president mainly processed the learning related to the policies and regulations. Through the government agency BPPT, the President learned that the solar home system positively impacted the people living in rural areas.

<u>From the 2000s – the 2020s</u>

In the post-financial crisis, the government announced the MEMR Regulation No. 17 of 2013. It introduced the feed-in-tariff (FiT) mechanism to re-establish renewable energy development such as rooftop PV. However, the FiT scheme was only implemented short term and dismissed after APAMSI protested the local content policy (Hamdi & IEEFA, 2019). One year after, in 2016, the government published the MEMR Regulation No.50 of 2016, which reintroduced the FiT mechanism. The regulation provided a fixed tariff between US$0.145/kWh and US$0.25/kWh depending on the location. However, the law was revised in early 2017 because of the massive impact on PLN revenue (Hidayatno et al., 2020).

In November 2018, the government introduced a net metering scheme where users can export the generated electricity to PLN and receive a payment of 65% of the current price. As a result, the rooftop PV installation was increased from only 1.6 MW in 2018 to 48.79 MW at the end of 2021. Considering the impact of the 65% payment scheme, the government introduced a new MEMR Regulation No. 26 of 2021, which increases the export-import kWh multiplier from 65% to 100%. This new regulation is expected to provide users with higher benefits and opportunities (Jati & IESR, 2022). The official government also stated:

> *"There are several regulations that we issue to support rooftop PV. Last year, we issued MEMR Regulation No.26 of 2021. The government hopes the regulation will encourage investment from the public, industrial or commercial, to support the RE program, especially rooftop PV."* (Interviewee #12, 2022)

To sum up, the learning process on policy and regulation occurred through the active interaction between the government, non-governmental organisations (e.g., APAMSI) and the incumbent electricity company PLN

c. User context development

Comparing the use of rooftop PV in the 1990s and recently, the types of users of rooftop PV has been shifted widely. In the 1990s, due to the absence of electricity access, rooftop PV was mainly used for solar home systems in rural areas. Applications such as in rural households, rural clinics, mosques, television, radio and water pumps were typical in the 1990s. In contrast, rooftop PV is currently widely used in urban areas, especially in the big provinces such as Jakarta and West Java. The applications of rooftop PV have shifted from rural to urban areas. Application in urban households, commercial and industrial sectors, government buildings, schools, train stations, airports, etc., has significant growth (Interviewee #9, 2022). Moreover, some interviewee believe that the rooftop PV will be widely used in the industrial sector due to the increasing International and market pressure (Interviewee #1, 2022; Interviewee #2, 2022; Interviewee #9, 2022).

The shift in the types of rooftop PV users might be influenced by the landscape factor of the financial crisis in 1997 and the development of the electricity grid by regime company PLN. Factors such as high-interest rates, decreasing income, and government support termination during the financial crisis impacted user willingness to use rooftop PV (World Bank, 2001). Moreover, the significant improvement of the electricity grid that can provide more stable electricity was likely influencing the local villager’s preferences.

Regarding public awareness, one interviewee stated that most Indonesian people are still unaware of renewable energy development (Interviewee #4, 2022). The lack of publicity from the government is mentioned to be the cause of low public awareness of renewable energy (Interviewee #4, 2022; Setyawati, 2020). Several NGOs, including IESR, have focused on arranging seminars, webinars and workshops to increase public awareness of renewable energy. As stated by one official staff:

> *"Increasing public or user awareness is one of the goals of my organisation. One of our programs is conducting seminars and webinars, which result from collaboration with the government, especially with local governments. We also see unequal access to information between big and less popular cities which resulted in the disparity in the installation of rooftop PV. Currently, solar power plants are concentrated in big cities such as Jakarta, Surabaya, and Bali. Besides seminars and webinars, we also try to do a workshop."* (Interviewee #7, 2022).

d. Industrial development

<u>During the introduction of rooftop PV in the 1980s-2000</u>

The industrial development of rooftop PV started to develop when the semi-commercial project in Lebak district, West Java, was introduced. The project aimed to measure the capability of a private company to manage the production and installation of many unit systems. To demonstrate it, five hundred units were installed in Lebak district, west java (de Quay, 1994).

The joint venture company, namely PT. R&S Rekadaya Energy Surya was responsible for the marketing, assembling, production, installation and maintenance of the systems. In commercialising rooftop PV, PT. R&S Rekadaya Energy collaborated with various technology suppliers, including international and local players. International suppliers supplied PV modules, regulators, batteries, and lamps. Meanwhile, the local company provided cables and inverters (de Quay, 1994). The international manufactured equipment was found to be of higher quality, but the availability of spare parts was low. During the project, some users had difficulty finding spare parts of international produced equipment such as batteries. To solve this problem, users experimented by using the locally produced batteries. The locally manufactured components benefited from lower prices and more readily available spare parts. However, locally produced components like batteries were found to be of lower quality and not fulfilling the specification of the manufacturers (Nieuwenhout et al., 2000).

<u>From the 2000s – the 2020s</u>

Interviewee #3 (2022) mentioned three necessary knowledge to develop the industrial sector: raw materials, manufacturers, and services. First, raw material knowledge is related to the research and development of raw materials for the PV components, such as the development of silicon into PV modules. Currently, Indonesia lacks research and development in raw materials. Although Indonesia has numerous raw material resources, most PV modules are imported from China (Interviewee #3, 2022). Local companies are gradually growing recently. For instance, one local manufacturer, Solar Quest, was launched in early 2019. The company was established in 1997 with a specialisation in clean room HVAC and building automation systems. Since 2019, the company has devoted itself to producing and investing in the R&D of solar panels. Interviewee #14 (2022) argued that the quality of Indonesia's local solar panel can compete with China's product; however, because of the small production unit, the local solar panel is not competitive enough in terms of price. To promote the local production sector, the government issued a new regulation which increases the local content law from 50% to 60%. The local manufacturers argued that this regulation protects local manufacturers established (Interviewee #14, 2022). In addition, compared to the early development stage of rooftop PV in the 1990s, more local manufacturing companies are currently involved in the rooftop PV industry.

Similar to the development of raw materials, the assembly of components is mainly carried out in other countries like China or Malaysia. Most solar modules in Indonesia are China's product and are imported from China, where the product currently dominate the world market (Interviewee #3, 2022). Lastly, the services sector is related to the market or business development. Since the government introduced the 65% net metering scheme, the services or business sector has been growing. It can be seen through several new players like start-ups providing different services and business schemes (Interviewee #9, 2022).

e. Environmental and social impact

<u>During the introduction of rooftop PV in the 1980s-2000</u>

During the demonstration project in Sukatani, the assessment of the socio-environment effect of the solar home system was conducted by BPPT. Reports made by BPPT show that several changes occurred after the introduction of solar electricity. Some of the changes are summarised in the following table.

Table 14 Environmental and social impact of the solar home system in Sukatani (de Quay, 1994)

Sector	*Changes*
Labour	• More shops opened until 10 pm • Industry increased production due to the possibility of working at night • Started a new job after getting the idea from a TV program
Consumption Pattern	• More young respondents spent twice on smoking and fast food • More people bought fashion in the city instead of in local stores • More people went to the city
Media Usage	a. The number of televisions, radio (taperecorder), and microphones (speaker) increased b. More people were watching TV every night
Education	c. Children were able to study more prolonged and more concentrated d. Educational programs were available
Religion	e. Activities associated with religion, such as praying at 5 am, had increased due to the availability of electricity for lighting and operating speaker
Social activities	f. Social activities reportedly increased

The survey conducted by the BPPT was a part of the learning process to understand the socio-environmental impact of the solar home system. In the demonstration Sukatani project, BPPT and R&S company concluded that solar home systems had many positive influences on society, such as increased labour, education, and religious activity. Although some negative impacts (e.g., raised consumption patterns) existed, the survey stated that there were no negative conceptions about the technology (de Quay, 1994). To sum up, the learning process associated with the environmental and social impact during the introduction of rooftop V in the 1980s-1990s was the survey and assessment conducted by BPPT.

<u>From the 2000s – the 2020s</u>

Multiple organisations arrange various activities to raise public awareness about rooftop PV. For example, Indonesia's rooftop PV association (PPLSA), established in 2016, organises a lot of socialisation and information dissemination to raise the public awareness. Moreover, PPLSA also conducts education and teaching session for the broader community (Interviewee #15, 2022). Other organisations that have contributed to raising public awareness are IESR and AESI. These organisations increase public awareness by conducting seminars, webinars and solar events (Interviewee #7, 2022).

Another initiative to raise public awareness is implemented by the university. In interview, the researcher and university representative stated that students are currently invited to make advertisements on social media (Interviewee #3, 2022). From the government side, one of the initiatives called 'Solar panel for school' was started to introduce and educate the students about the renewable energy. This initiative is a collaboration between the West Java provincial government with Earnest Young organisation. In addition, the West Java provincial government also initiated the installation of rooftop PV in schools. This initiative aims to educate the student (Interviewee #6, 2022).

f. Energy potential

<u>During the introduction of rooftop PV in the 1980s-2000</u>

Studies on the potential of solar energy at the time of the introduction of the solar home system in the 1980s – 1990s were conducted by multiple organisations such as R&S company and BPPT. In the design system phase, solar energy was studied through calculation. The solar energy radiation was estimated at around 3.5 kWh/ m^2/day. Moreover, the solar energy potential was measured based on recorded data during the monitoring at Sukatani from 1989-1990. The in-plane irradiation was approximately 4.2 kWh/m^2/day (20% higher than the estimated value for the system design). In other cities, such as Medan and Samarinda, the solar potential measurement was conducted using pyranometers (Reinders & Sudradjat, 1999).

According to Reinders & Sudradjat (1999), the solar radiation profile in Indonesia was distinguished based on the season. At the end of the hot season (September – October 1991), the maximum daily irradiation reached 6.8 kWh/m^2/day, higher than the maximum daily irradiation during the middle of the rainy season, 6.8 kWh/m^2/day (January – February 1992). Regarding the Sukatani village, the solar energy irradiation was equal to or slightly higher than the average irradiation in Indonesia.

<u>From the 2000s – the 2020s</u>

The study on solar energy potential was conducted by various stakeholders, including the government, university and NGO. Table 15 highlights several studies that are identified in Silalahi et al. (2021).

Table 15 Study on Indonesia's solar energy potential (adopted from Silalahi et al. (2021))

YEAR	TYPE OF STAKEHOLDER	NAME	RESULT
2013	University	Veldhuis and Reinders	The total potential of grid-connected solar is 1000 GW and could generate 1500 TWh of electricity (Veldhuis & Reinders, 2013).
2017	NGO	IRENA	Rooftop PV can generate 533 GW (IRENA, 2017)
2019	International Agency	World Bank	Indonesia's solar energy potential is 500 GW (Puspa, 2019)
2019	NGO	IESR	Residential rooftops have a potential for solar energy in the range of 194 GW to 655 GW (IESR, 2019)
2020	University	Vidinopulus	Per year, Indonesia's solar potential is approximately 26,000 TWh (Vidinopoulos et al., 2020)
2021	Government	MEMR and PLN	Solar energy potential is 208 GW (PLN, 2021b)
2021	University	Silalahi	Indonesia's solar energy potential is estimated to be larger than 200,000 TWh/year, which includes the floating solar potential ((Silalahi et al., 2021)

g. Business model

<u>During the introduction of rooftop PV in the 1980s-2000</u>

Besides the incumbent electricity business model, another two business models existed during the diffusion of the solar home system in the 1990s. The two forms of business model were the cooperative model and lease scheme model. To help the local people manage the financial and technical aspects of the solar home system, KUD, through the cooperative business model, provided an intermediary service between the local villages and private companies (suppliers and banks). KUD were responsible for the credit administration, system maintenance and organising the collective purchase of the spare part (de Quay, 1994). However, the role of the cooperative business model by KUD seems to have gradually declined due to the decreased government incentive after the financial crisis. Moreover, the shift of user segmentation from rural to urban areas also affecting the cooperative BM that mainly focused on rural areas.

The second business model was the lease scheme offered by intermediaries such as NGOs. Under the leasing scheme, the ownership of the system was retained by the intermediary until the cost was repaid by the user. Most lease scheme for the solar home system was set up with low or zero-interest loans (Cabraal et al., 1996)

<u>From the 2000s – the 2020s</u>

In the post-financial crisis, two business models associated with rooftop PV exist. The two business models are host-owned and third-party-owned business models (lease and rental scheme). The host-owned business model was encouraged by the introduction of the fit-in-tariffs scheme. The business model allow the user to benefit from the FiT scheme. Meanwhile, the third-owned-party business model is inspired by the high-up-front cost barriers that users face. Through this model, the user can utilise the rooftop without necessarily paying the high initial fee. In chapter 7, the business model is described and analysed.

In summary, two innovative (cooperative and leasing model) was resulted in the diffusion of the solar home system during the 1980s – 2000. However, the impact of the financial crisis of 1997 on the regime level (government change and termination of government incentives) caused the declination of the cooperative business model. During the 2000 – 2020s, two new innovative business models (host-owned and rental model) resulted during the innovation process

6.3 Empowerment

The majority of the rooftop PV installation is an on-grid system where PV is connected to the PLN grid (Interviewee #15, 2022; Interviewee #4, 2022). Since the rooftop PV installation must be connected to the PLN grid, the niche development is still highly dependent on the incumbent company. In Indonesia's current monopolistic electricity sector, where the majority is controlled by the incumbent company, there is little possibility for rooftop PV niche actors to apply stretch and transform empowerment. Moreover, considering the hesitancy of incumbent PLN to massively use rooftop PV due to its potential impact on PLN revenues and the oversupply situation, it is difficult for niche actors to replace the regime structures in Indonesia.

Currently, niche actors use fit and conform empowerment. Niche actors continuously adjust their strategy with the current condition and incumbent PLN through several methods such as discussion with PLN, socialisation to increase public awareness, government advocation, and innovative business models (leasing, loan, etc.).

6.4 Barriers and Opportunities

This section presents the barriers and opportunities in rooftop PV development. Barriers are categorised into financial, institutional, policy, technical and awareness barriers. The analysis is based on interviews and desk research.

6.4.1. Financial barriers

Private companies such as developers face profitability constraints due to the current electricity price, which is considerably low due to the subsidy policy. According to Interviewee #8 (2022), to increase the attractiveness of the product or service, the rooftop PV developers are currently forced to sell solar panels at very low prices or 10-20% lower than the subsidised PLN tariff. Although this low price increases the competitive level of rooftop PV in the market, selling the product at very low prices decreases private companies' revenue. In addition, in the absence of the government incentive to the private company, the entire investment risk for rooftop PV installation is borne by the business actors (Interviewee #8, 2022). These financial and profitability issues are currently hindering the rooftop PV niche development business activity. The complete statement of one official developer is presented as follows:

> "*If we look at the current price of electricity, the selling price of rooftop PV electricity depends on the selling price of PLN. As developers, we are not allowed to sell electricity directly to consumers. We can only sell services or rent, so our contracts with clients are power contract agreements where our prices should not be higher than PLN rates (e.g. 10-20% lower). This sometimes makes the return not as good as other infrastructure projects. And usually, if the price of PLN goes up, our costs go up and vice versa. We see that this uncertainty is very high. While we know this rooftop PV is helping the government and our clients reduce costs, all the risk is in our hands as developers. So there is no government support, such as fiscal incentives or ease for developers to get permits*" (Interviewee #8, 2022)

Furthermore, profitability barriers are also faced by the potential users. Due to the high price of solar panels and the limitation of installed capacity by PLN, the return of investment on rooftop PV is significantly declining. According to the user representative, the price of rooftop PV is still relatively high for Indonesian people. With the high up-front cost and low net metering fee, the payback period is estimated to be around seven years, a considerably long investment in Indonesia. Moreover, many customers are concerned about the additional cost during the initial seven-year operation (Interviewee #15, 2022).

This statement is supported by the survey by Setyawati (2020). According to the study, the cost of PV is considered too expensive for Indonesian households. Moreover, the 8-10 years payback period would be too lengthy. Two survey respondents recommended that five years long-term return on investment would be more acceptable (Setyawati, 2020).

6.4.2. Institutional barriers

The identified institutional barriers are mainly related to the dominant regime grid operator, PLN. Three obstacles are analysed: permits issued by PLN, capacity limitation, and PLN revenue reduction.

Permits from PLN

Most of Indonesia's electrical system (distribution and transformation) is operated by the state-owned company PLN. In several interviews with stakeholders, the PLN was cited as the main stakeholder in blocking rooftop PV diffusion in Indonesia. For instance, one of the issues regarding the permits from PLN is addressed by one rooftop PV developer in the following statement:

> *"The problem is more towards permits and licenses because we have to wait for approval from PLN before installing rooftop PV. For example, through a lease scheme, I have made a deal with the user where we have to ask for permission from PLN. According to the Law, the response should be one week. However, there has been no response for five months. And some projects are rejected and limited by PLN."* (Interviewee #1, 2022)

According to MEMR Regulation No.26 of 2021, rooftop PV installation requires approval from the electricity operator PLN, which must be granted within five business days (Ashurst, 2021). However, PLN has not complied with this MEMR regulation. Therefore, due to the lengthy approval process and a high potential for rejection, the permit process from PLN is an obstacle faced by niche actors like projects such as project developer companies (Interviewee #1, 2022; Interviewee #2, 2022).

Limitation of installed capacity

Another issue at the regime level blocking the rooftop PV dissemination is the limitation of installed capacity by the PLN. As mentioned by users representatives:

> *"The problem faced is the implementation of the regulation where PLN, although not announced publicly, internally said that they only approve 10 - 15% of the installed capacity. This becomes a problem for business and industry parties because this policy reduces user potential cost savings and becoming economically unattractive."* (Interviewee #15, 2022)

In the MEMR Regulation No.26 of 2021, the rooftop PV is allowed to be installed up to a maximum of 100% of the connected power of PLN (Ashurst, 2021). Despite the regulation, the PLN is currently limiting the capacity of rooftop PV with a maximum of 10 – 15% of the connection capacity. The limitation will reduce the economic benefit of rooftop PV, which hinders the user's willingness to adopt rooftop PV.

Oversupplied and PLN Revenue reduction

From PLN's perspective, the massive use of rooftop PV will reduce the company revenue, especially in the Java-Bali system, which is under an oversupply condition. Two official staff from the electricity operator, PLN, stated:

> *"Indonesia's desire to achieve EBT where PV is built massively will hamper PLN in selling electricity. From PLN's perspective, we also want to protect our revenue."* (Interviewee #10, 2022)

> *"PLN must be careful in implementing rooftop PV because of oversupply and cash flow from PLN where electricity rates do not increase, and subsidies are continuously reduced."* (Interviewee #11, 2022)

Both statements from two official staffs of PLN show the hesitancy of PLN to support the development of rooftop PV due to oversupply issues and its potential to reduce the company revenue. The oversupply in the Java Bali system was primarily caused by the acceleration of coal-based electricity power generation in the last two decades (Woods, 2017). This significant increase was due to two Fast Track Programs conducted in the Yudhoyono government regimes (2004 – 2014) and a 35,000 MW initiative established by the current President Widodo, which aims to boost electricity generation in Indonesia (Mori, 2020).

6.4.3. Policy barriers

In the interview, respondents mentioned that the lack of clarity on the regulation hinders the large-scale diffusion of rooftop PV in Indonesia. It can be seen in the change of MEMR regulations during 2018 – 2021, in which the regulations have been amended three times (Bellini, 2021). Although the current MEMR regulation is considered by many actors to be more supportive (due to the improvement of the net metering factor from 65% to 100%, extending the credit accumulation period, and shortening the permit approval timeframe from 15 to 5 business days), many business actors considered the frequently change in regulation as one uncertainty and obscurity of the policy. Moreover, the non-compliance of PLN with this regulation increases tension for business people (Interviewee #7, 2022; Interviewee #8, 2022; Interviewee #9, 2022). One of the manufacturer's staff stated:

> "*The main problem with regulation is that it changes frequently. Many actors are still waiting and see for stable regulations before getting involved in the market*." (Interviewee #5, 2022)

The second obstacle mentioned by developers and EPC companies is related to the local content policy. Many business actors consider increasing the percentage of the domestic component to 60% as an obstacle to the development of rooftop PV. The 60% local content policy forces the value chain actors, such as EPC and developer companies, to utilise local components at higher prices. In this case, the

60% local content policy will potentially decrease the economic benefit of the rooftop PV business actors due to the higher price (Interviewee #1, 2022).

> "*One of the obstacles is the level of the domestic component (TKDN). TKDN, which is 60%, is one of the obstacles to being economical. For a large scale, 60% TKDN makes the cost more expensive than the current cost of generation (BPP)."* (Interviewee #1, 2022).

Although the developers and EPC companies consider the local content policy as an obstacle to rooftop PV diffusion, this policy was issued by the government to protect the local suppliers. In the following statement, the representative local manufacturers explained that the local content policy provides protected space for local manufacturers.

> *"…. there are regulations such as TKDN that help manufacturers a lot. So that local manufacturers can develop and survive in Indonesia because we want to prioritise local projects because the numbers are very massive. However, if the mandatory does not exist, it will be tough for local manufacturers.*" (Interviewee #14, 2022).

6.4.4. Technical barriers

Compared to neighbour countries such as Malaysia, which have many local manufacturers, Indonesia currently lacks local manufacturers that could meet the needs of the local market and the policy (Interviewee #3, 2022). According to APAMSI (2022), the local suppliers are currently able to achieve 46.05% of local content and incapable meet the 60% requirement of the domestic component. The incapability of local manufacturers to produce good quality with competitive price product are another obstacle in Indonesia's rooftop PV industry. Moreover, one respondent from a state-owned energy company stated that Indonesia currently lacks human resources and companies capable of locally developing good-quality PV components (Interviewee #4, 2022). One official local supplier representative and an official from a state-owned energy company explained:

> "*Another obstacle is the module from China, where we can't compete with China because of this suppliers price. But fortunately, there are regulations such as TKDN that help manufacturers a lot. So that local manufacturers can develop and survive in Indonesia because we want to prioritise local projects because the numbers are very massive. However, if the mandatory does not exist, it will be tough for local manufacturers*" (Interviewee #14, 2022)

Therefore, the incapability of local producers to fulfil 60% local content and produce competitive products and the lack of human resources are problems that need to be solved for further rooftop PV diffusion.

6.4.5. Awareness barriers

Lack of information and campaign to the general public The awareness of Indonesian people on renewable energy development, particularly rooftop PV, is also become a concern by several respondents. During the interview, the director of research at the Tropical Renewable Energy Centre University of Indonesia explained that many Indonesian people are still unaware of renewable energy development. The respondent emphasised that the absence of advertisements for renewable energy compared to other products (e.g. water pumps) is one of the reasons for the low public awareness (Interviewee #4, 2022).

> *"Compared to water pumps, there is no advertisement for rooftop solar panels in Indonesia. Indonesia needs something like this to increase public awareness. In Europe, this is not necessary because they are already aware of this issue. In this case, in Indonesia, there are no advertisements that convey rooftop PV."* (Interviewee #4, 2022)

According to the survey conducted by Setyawati (2020), 59% of respondents were unaware of the MEMR regulation No.49/2018 that PLN customers are allowed to install PV systems while connecting to the grid. Many respondents in the survey commented that the lack of campaigns to the public about the renewable energy regulation is the reason for low public awareness. Some respondents in the survey recommended the government to disseminate renewable energy information through community association networks (or *Rukun Tetangga/Rukun Warga*), television and newspaper (Setyawati, 2020).

Limited awareness and participation of local leaders and peoples

Another obstacle to rooftop PV diffusion is limited awareness and low involvement of local people and leaders. According to one respondent, the awareness of residential sectors is deficient because most of the niche innovation activities are conducted in the big cities such as Jakarta, Bandung and Bali (Interviewee #7, 2022). Moreover, the perception of local leaders that entire electricity generation development is the PLN's responsibility disincentivises the provincial government to reform their local power sectors. These conditions that are more common in urban areas are blocking the diffusion of rooftop PV in Indonesia (Fathoni et al., 2021)

6.4.6. Opportunities

High solar energy potential

The rooftop PV diffusion in Indonesia is very promising because high solar energy potential and uniform distribution across the country (Silalahi et al., 2021). According to PLN (2021), solar energy in Indonesia has a significant potential (208 GW), almost half of Indonesia's total renewable energy (443 GW.). Considering the low installation rate (0.04%) and the enormous resource, solar panel technology such as rooftop PV still have a higher potential to grow in the future.

Increasing demand

Besides the solar resource potential, the growing market is another opportunity for rooftop PV niche development. The demand for rooftop PV in Indonesia is increasing due to the support from the policy and International pressure on the industrial sector to use green energy (Interviewee #1, 2022;

Interviewee #2, 2022). As explained previously, the rooftop PV systems have become a National Strategic Project (PSN) to achieve a renewable energy target of 23% in 2025. This motivates the government to supervise several incentives, including 100% net metering scheme and financial incentives, which resulted in the growing market. Moreover, the landscape factor of International and market pressure (explained in chapter 5) forces several industrial sectors to utilise rooftop PV as the strategy to develop rooftop PV.

Growing business model and actors

Another opportunity mentioned by several respondents is related to Indonesia's growing business model and actors. One respondent explained that the innovation of the business model, namely the rental scheme (discussed in the next chapter), eliminates the high up-front cost of rooftop PV installation. This new business model is a new opportunity for rooftop PV diffusion (Interviewee #2, 2022).

> *"A rental scheme is already feasible. As the issue in Indonesia, many could not adopt rooftop PV because of the large down payment. So through this rental scheme, the community does not need to spend a large amount of investment for the down payment. This is one of the breakthrough schemes in Indonesia that makes the solar industry in Indonesia increasingly up and booming."* (Interviewee #2, 2022).

Another opportunity is the growing number of actors involved in rooftop PV. As explained previously, various new actors such as coal companies and venture capitalists are participating in rooftop PV diffusion. One respondent considers these factors as the opportunities that present the positive niche environment of rooftop PV development (Interviewee #9, 2022).

Technical opportunities

In the interview, many respondents considered the rooftop PV have technical opportunities compared to other technologies. According to Interviewee #1 (2022), rooftop PV systems are easier to implement than other technologies, such as steam-electric power generation. Moreover, the rooftop PV installation does not require ample space and extensive technology like wind turbines (Interviewee #9, 2022). The other respondent added that rooftop PV could be quickly constructed compared to other technologies, which becomes an alternative technology for the government to reach sustainable goals (Interviewee #13, 2022).

Numerous roof availability

Another opportunity for rooftop PV niche development is the availability of roofs in Indonesia. The user representative explained that the availability of roofs in Indonesia is more significant than in other countries. The reason is that most houses in Indonesia are one-floor houses, which provides more space for rooftop PV than apartments (Interviewee #5, 2022). The statement by the respondent is presented as follows:

"The opportunity for rooftop PV is the availability of the roof, whereas, in Indonesia, the type of house is a land house. So, the availability of a roof is much greater than in countries where people live in apartments. Even a straightforward home or one floor, rooftop PV is very beneficial because it has access compared to living in a multiple floors house." (Interviewee #15, 2022).

6.5 SNM Analysis Conclusion

a. SNM Application

SNM framework is used in this thesis to analyse the niche activities in rooftop PV development in Indonesia. Several niche processes are examined: (1) Shielding, (2) Nurturing, and (3) Empowerment. The analysis results are summarised in table 16.

Table 16 Summary of SNM analysis

Niche Process	**Aspect Analysis**	**1980s – 2000**	**2000s – 2022 (Present)**
Shielding	Active	Government incentive, 50 MWp rural project, and international donors	Feed-in-tariff, financial incentives, focus group discussion, adoption in all gas stations, and bulk purchasing
	Passive	-	A national movement for one million rooftop PV, installation in government owned-building, and collective activities by NGOs
Nurturing	Actor's expectations	-	Mostly positive, but some issue
	Factor shaping expectation	Rural electrification, financial crisis, and government change	Energy security, climate change, market pressure, covid-19 and frequently government change
	Composition of social networks	R&S private company, DGIS, BPPT, government, International financial institutions, rural villagers technology supplier	Government, PLN, international agency, developer, EPC, financial institutions, NGO, researchers, users
	Alignment of social networks	Solar home system demonstration project and project of "50 MWp PV rural electrification".	GNSSA, initiatives by NGO, FGD, and installation permit process with PLN
	Learning – Technical	Problem and solution discovery, the user needs identification, technology adjustment, and transfer knowledge.	Research and development activity, seminar, workshop, exhibition and conference
	Learning – Policy and regulation	The government learned from the pilot project Sukatani	Active interaction between stakeholders
	Learning – User context	Focus on rural areas	Shift from rural to urban areas
	Learning – Industrial	Collaboration with international and local supplier	Low local manufacture and high services (many new actors involve)
	Learning – Social impact	Learning through surveying local people	Socialisation, teaching session, seminar, webinar and event

	Learning – Energy potential	Through estimation and monitoring	Studies conducted by various stakeholders
	Learning – Business model	Cooperative and Lease model	Host-owned and Third-party-owned (lease and rental). Cooperative business model role declined due to financial crisis and shift of users
Empowerment		Stretch and transform	Stretch and transform

b. Barriers and Opportunities

Barriers to rooftop PV niche development are categorised into six classifications: (1) financial and profitability barriers, (2) institutional barriers, (3) policy barriers, (4) technical barriers, and (5) awareness barriers. The financial and profitability barriers are caused by the uncertainty in revenue, the absence of government incentives for business actors, high up-front costs, and a long payback period. The first two causes (revenue uncertainty and lack of government incentives) become obstacles for business actors such as developers and EPC companies. Meanwhile, the high up-front cost and long payback period reduce potential users' willingness to adopt rooftop PV.

The institutional barriers are associated with the current regime, PLN. Some issues, such as installation permit from PLN, limitation of installed capacity, and PLN revenue reduction, are currently hindering the wide diffusion of rooftop PV. The business actors face other problems such as regulation clarity and local content policy. In terms of technical barriers, local manufacture's incapability to comply with the regulation is mentioned by several interviewees. Lastly, the low public awareness and limited campaign influence the slow growth of the rooftop PV market.

With the enormous energy solar potential, the trend of increasing demand, and a growing number of business actors, the rooftop PV niche development should be supported by the stakeholders. To accelerate the wide diffusion of rooftop PV, these six classifications of barriers need to be overcome.

CHAPTER 7 – BUSINESS MODEL ANALYSIS

This chapter aims to analyse the role of business models in the niche development of rooftop PV. This chapter is divided into three sections: the rooftop PV business model in Indonesia, the analysis of business model roles, and conclusions. The first section discusses the business model associated with the rooftop PV niche development. Then, the business model is described in the business canvas founded by Osterwalder et al. (2010). In the second section, to what extent is the business model influencing rooftop PV niche development is answered. And lastly, the chapter conclusion is provided.

7.1 Rooftop PV Business Model in Indonesia

7.1.1. State-owned Electricity Company PLN

This section describes the business model of the incumbent utility company in Indonesia, PLN. The description of PLN's business model is provided according to the interview with PLN respondents, PLN reports, and desk research such as the company website. Figure 18 presents the PLN's business model canvas based on analysis results.

a. Value Propositions

The value proposition of the incumbent electricity company's business model is to provide affordable, reliable and accessible electricity services to the Indonesian public. As a state-owned electricity company, the business model must comply with government regulations and public interests. Moreover, the PLN business model needs to generate profits and revenue as the business entity (PLN, 2022).

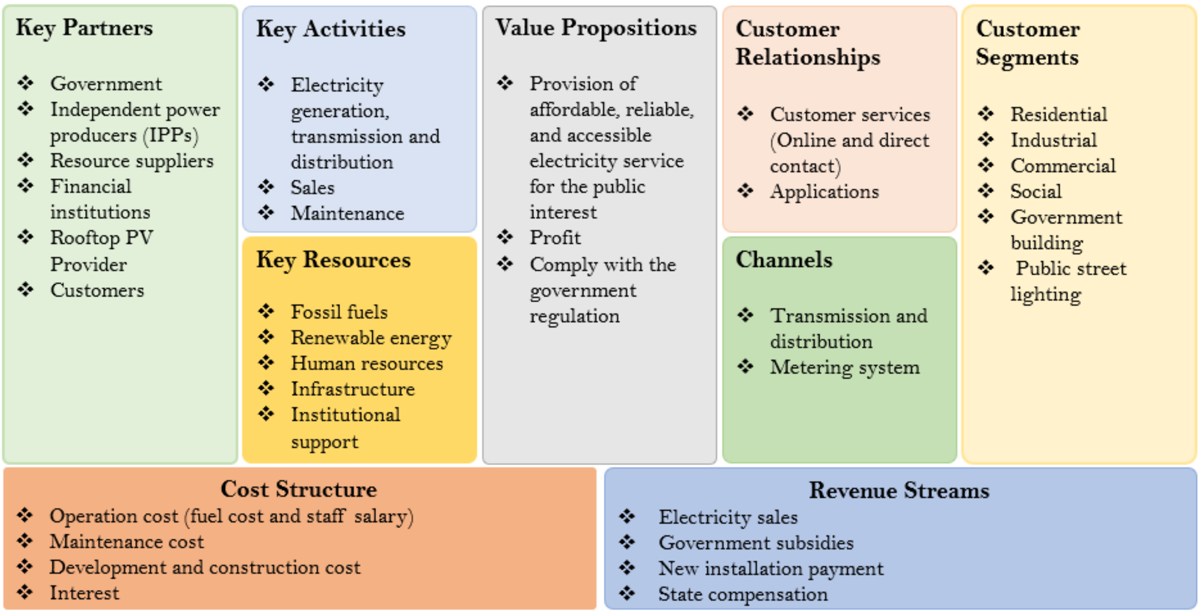

Figure 18 PLN's business model canvas

b. Key Partnership

Since one of the value propositions is to comply with government regulation, one essential partnership of PLN is the government. The government give a mandate to PLN to manage the electricity sector in Indonesia. The government is also responsible for regulating the electricity tariffs and supervising the electricity sector. Moreover, the government also develops and designs the electricity development plan that must be complied with by PLN (Interviewee #12, 2022).

The next important partnership of PLN is resource suppliers such as coal, gas, and oil company. Coal, gas and oil suppliers play a significant role as fuel suppliers for PLN to generate electricity. PLN often buy coal, gas and oil through long-term contracts and commitments with suppliers (Pribadi, 2021; Reuters, 2020). Another essential partnership of PLN is Independent Power Producer (IPP). IPP is private companies permitted by regulation to generate and sell electricity to PLN. In this case, IPP supports PLN to meet the electricity demand in Indonesia. Through the Power Purchase Agreement (PPA), IPPs can sell electricity to the PLN.

Furthermore, in developing the electricity services (generation, transmission, and distribution), the PLN collaborate with technology suppliers and lenders. The technology supplies electrical equipment such as generators, turbines, towers, etc. Meanwhile, lenders such as banks or financial institutions provide funding or loans to PLN to expand the services. And lastly, the consumer is another key partner that purchases and consumes the electricity generated by PLN.

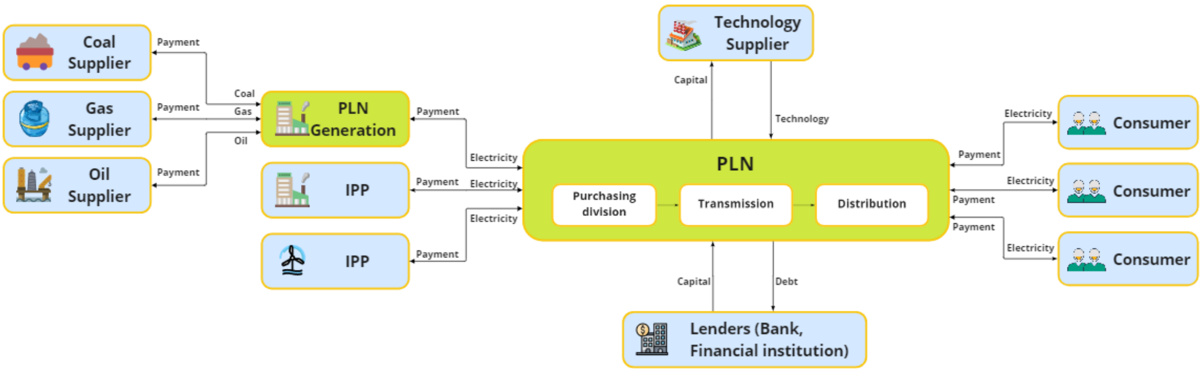

Figure 19 The structure of incumbent utility company business model

c. Key Activities

The business activities of PLN cover all activities in the value chain of electricity. Three main business activities are conducted by the PLN: electricity generation, transmission and distribution. By 2020, PLN controlled approximately 60% of the energy generation in Indonesia (MEMR, 2021b). Meanwhile, PLN operates all transmission and distribution systems in Indonesia, which is a mandate by the regulation. Another key activity of PLN is electricity sales. In MEMR regulation, PLN becomes the sole stakeholder allowed to sell electricity directly to the customers (Setyawan, 2014). Moreover, PLN should ensure the resource from coal, gas, and oil company by managing the long-term contract and commitment. Lastly, the power purchase agreement (PPA) with a private electricity generation company should be arranged by the PLN.

d. Key Resources

The key resources for business activities of PLN are fossil fuels and renewable energy. According to PLN (2020), the main resources for electricity generation of PLN mostly come from fossil fuels (approximately 90%), such as coal (63.6%), gas (22.5%) and oil (4.8%). Meanwhile, renewable energy contributes nearly 9.5% of the electricity production of PLN. Renewable energy consists of hydro, geothermal, wind and solar. Another main resource that PLN own in business activities is infrastructure. In 2020, the PLN have 39,100 MW power plants, 48,800 km transmission line with 1,740 substation, and 920,522 km distribution lines with 471,765 substation (MEMR, 2021b). Moreover, at the end of 2020, PLN had 53,385 staff with a productivity level of 4,562 MWh/staff and 1,480 customers/staff (PLN, 2020b).

e. Customer Relationships

PLN maintains customer relationships by providing customer services through online and direct contact. PLN uses social media, websites and emails to engage with the customer. Moreover, in 2020, PLN launched a new mobile application, called PLN Mobile, as a digital platform to provide convenience for the customer. Through PLN Mobile, customers can purchase tokens for prepaid customers, make payments and monitor electricity usage. Moreover, through the application, customers can submit complaints and receive information related to the electricity issue, such as blackouts and power failures (PLN, 2020a).

f. Customer Segments

PLN customer segments are categorised into six types of customers: residential, industrial, commercial, social, government building, and public street lighting. The residential sector consumes the largest amount of electrical energy by consuming 46% (12,156 GWh) of total electricity produced by PLN. Industrial and commercial sector consume 29.66% (72,240 GWh) and 17.58% (42,819 GWh), respectively. Meanwhile, the other segments (social, government building, and public street lighting), in total, consume 6.71% (16,368 GWh) of total electricity (PLN, 2020b).

g. Channels

As mandated in the regulation, PLN is the sole stakeholder allowed to sell electricity directly to the consumer. To distribute the electricity, the PLN owns and manages all transmission and distribution systems in Indonesia. A metering system is also installed in each PLN's customer to measure the capacity used by the consumer. Moreover, PLN currently plans to establish a smart-meter system to automate the billing and measurement system (Harsono, 2020).

h. Cost Structures

According to the financial statement of PLN (2021), the cost structure of PLN consists of several elements: (1) operation cost, (2) maintenance cost, (3) interest and (4) another cost. The operation cost contributes to around 81% of the total cost. The operation cost is used to purchase coal, gas, and oil (36.63% of the total cost), to purchase electricity from IPP (32% of the total cost), to pay staff salary (7.7% of the total cost) and to rent equipment (1.47% of the total cost). Meanwhile, the maintenance cost contributes 7% of the total cost (PLN, 2021a).

i. Revenues Streams

The revenues of PLN in 2021 came from electricity sales (78.45%), new connections installation fees (0.1%), government subsidies (13.52%), state compensation (6.67%), and other income (1.2%). In 2021, the total revenue of PLN was IDR 368.17 trillion (or 24.47 billion euros) (PLN, 2021a)

7.1.2. Host-owned Business Model

The host-owned business model is a business scheme where the users own the rooftop PV system and the property on which the PV system is installed (Cai et al., 2019). This business model is commonly offered by rooftop PV provider companies such as EPC. In Indonesia, most EPC companies provide the host-owned business model through buy-out schemes allowing the user to install and own the PV system in their building (Interviewee #2, 2022). The business canvas of the host-owned business model is described as follows.

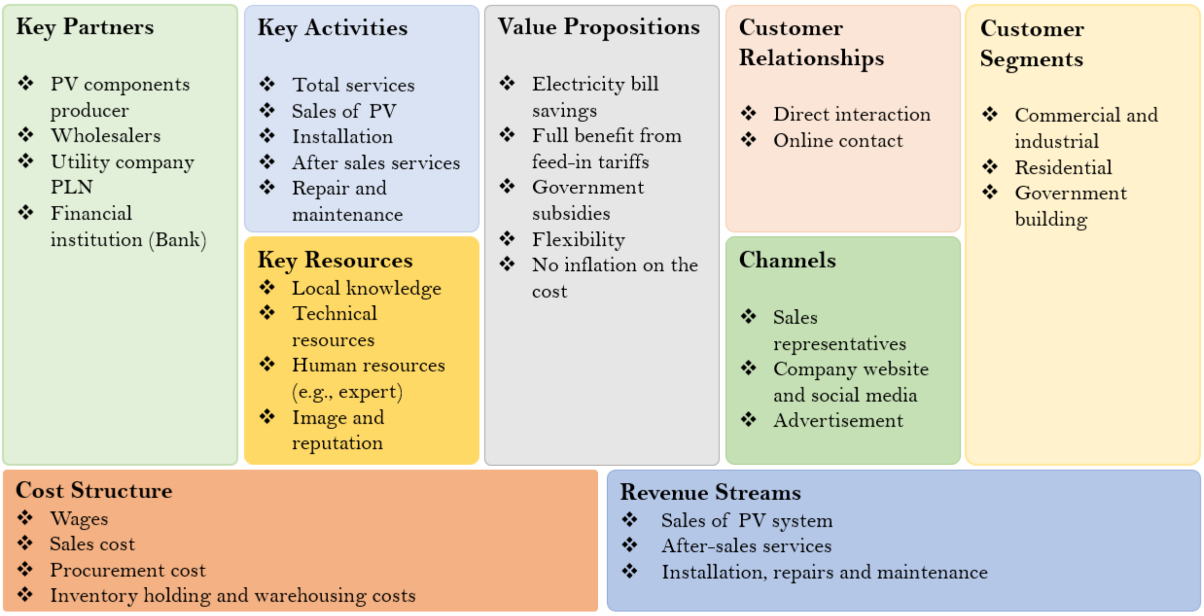

Figure 20 Host-owned business model canvas

a. Value Propositions

This section describes the value creation companies perform for their customers using the products and services offered. First, this business model allows users to be more independent of utility companies in producing energy and become "prosumers" to produce energy. With the ability to make energy, customers can reduce their electricity bills (Interviewee #8, 2022). Secondly, customers can fully benefit from the export-import electricity policy, where the excess power generated from rooftop PV systems can be exported to the grid (PwC Indonesia, 2021). Subsequently, the customer also can receive the rooftop PV incentive from the government and UNDP, which will increase the economic benefit of the investment (MEMR, 2022b). In this business model, the EPC companies provide the customer with PV components, installation, repairs and maintenance services. EPC companies also offer flexibility where customers can install the PV system alone (Interviewee #2, 2022). Lastly, inflation will not influence costs due to the buy-out scheme (ATW Solar, 2022).

b. Key Partnership

The producer and wholesaler of PV system components (e.g., inverter and solar panels) are critical partners in providing the technology to solar PV companies. Secondly, the utility company, PLN, is another essential partner because of the direct connection to customers and its power to approve or reject the PV system installation permit (Interviewee #10, 2022; PwC Indonesia, 2021). In this case, solar PV companies need to build a cooperative relationship with PLN to ensure a successful grid connection. Another key partner is lenders such as banks and financial institutions to provide loans to the customers (Interviewee #1, 2022).

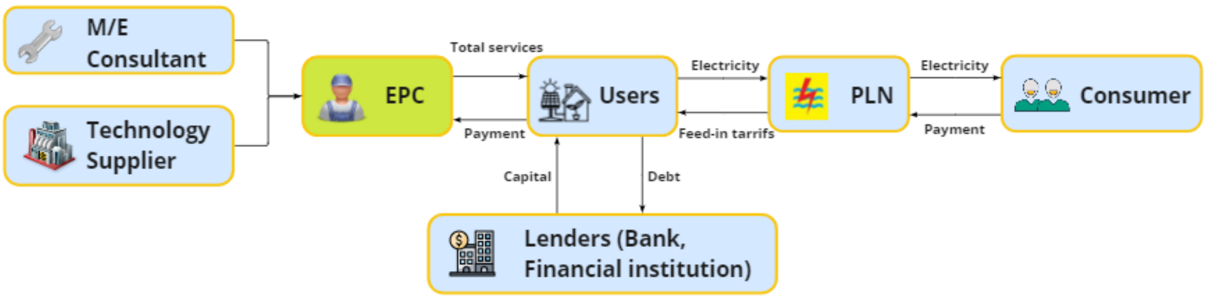

Figure 21 The structure of host-owned business model

c. Key Activities

Most rooftop PV companies in the Indonesian market provide total service solutions, which include surveying potential rooftop areas, calculating installed capacity, designing the system, arranging the permit, purchasing components, system installation, and performance monitoring as well as repair and maintenance services (Interviewee #2, 2022). Companies can also sell only the PV system to the customer with the training program for installation and operation while the customer carries out the installation. Moreover, companies also offer separate after-sales service and repair and maintenance programs. Some companies also provide an application to monitor the daily performance of rooftop PV.

d. Key Resources

One critical resource for solar PV companies is knowledge of the local market, such as relationships with local stakeholders (e.g., government, customers, communities, and financial institutions). One EPC company business developer stated that communicating with stakeholders such as the customer is one way to learn about the market needs (Interviewee #2, 2022). According to Cai et al. (2019), other vital resources for PV companies in the host-owned business model are technical and human resources. Adequate technical resources and having experts contribute to providing better products and services for customers. Lastly, company image and reputation are essential to attract more customers and partners and create a competitive advantage in the market.

e. Customer Relationships

A good customer relationship is an influential factor in creating a successful business (Interviewee #2, 2022). Moreover, building a good relationship with the customer can significantly remove public awareness barriers about rooftop PV technology (Cai et al., 2019). Most rooftop PV providers in Indonesia maintains a relationship with customer through direct and online interaction. Before purchasing, the salesperson usually surveys the client and evaluates the condition, such as the location, rooftop condition and size, electricity installed capacity, and the current load. Next, the PV company propose a PV systems scheme to the customer. And finally, before the installation process starts, the price negotiation and contract agreement are held (Interviewee #2, 2022). The customer relationship is maintained through the website, email and social media.

f. Customer Segments

The host-owned business model covers all target market segments in Indonesia, including industrial, residential and government buildings. The industrial sector with high capital is essential for rooftop providers under this business model. Although this business model is not popular in the residential sector due to the high up-front cost, most rooftop PV companies still offer this business model to the residential segment. Customers such as high and middle-income families and technology pioneers are essential as target customers (Interviewee #15, 2022). The last customer segment is government, especially after the regulation to install rooftop PV in a government building was introduced.

g. Channels

The use of identified channels is strongly associated with customer engagement. The interaction between rooftop PV companies and customers is commonly undertaken through a salesperson. Most rooftop PV companies have a sales division in the structure. Secondly, the rooftop PV company usually publish information or promotion through the company website and social media such as Instagram, LinkedIn, etc.

h. Cost Structure

The cost structure is analysed according to information in previous parts of the business canvas. As mentioned previously, the expert staff and salesperson are critical components in creating an excellent product and building good customer relationships. Therefore, wages and sales costs are substantial elements in the cost structure. Secondly, EPC companies purchase PV components such as inverters, panels, cables, etc., from technology suppliers. In this case, procurement costs emerge in the cost structure. Lastly, some companies are stocking and warehousing the PV system components, which need additional costs.

i. Revenue Streams

The primary income of rooftop PV companies comes from sales. Another payment is received from other vital activities such as after-sales service, where customers pay additional fees. In addition, under this business model, the cost of repair and maintenance is also the income for the rooftop PV provider.

7.1.3. Third party-owned Business Model: Leasing and Rental Scheme

The third-party-owned business model was first known in the United States in 2005, and various models exist in other countries, including the Netherlands, Denmark, China, and German. Generally, this business model consists of two payment schemes: Power Purchase Agreement (PPA) or lease construction (Horváth & Szabó, 2018). In Indonesia, the PPA scheme is usually known as performance-based rental payment. Because the policy does not allow the PPA scheme, most developer companies only apply the lease business model. The difference between the two schemes is described in the revenue streams section. The advantage of a third-party-owned business model is that it eliminates several financial barriers, such as high up-front costs for a residential customer. The business canvass of the third-party-owned business model is described as follows.

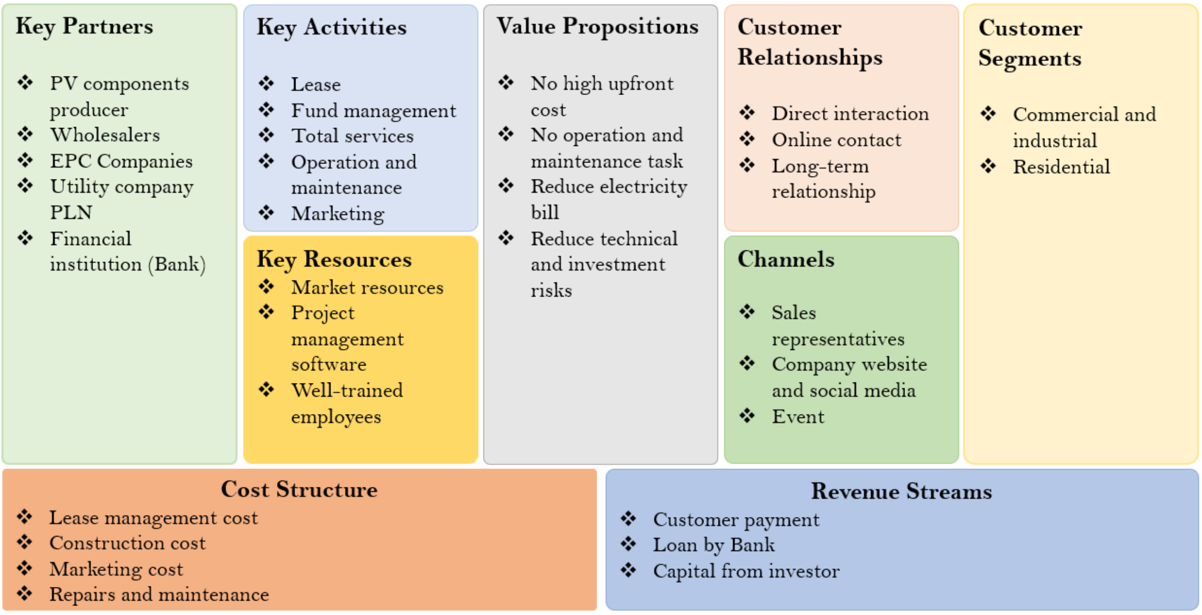

Figure 22 Third-party-owned business model canvas

a. Value Proposition

As mentioned previously, the most significant advantage of the third-party-owned model compared to other business models is the model allows customers to install PV and use renewable energy without paying the high upfront cost. In this case, the business model offers a more affordable system for the customer, leading to the acceleration of rooftop PV diffusion (Interviewee #2, 2022). The second value proposition is that the model removes the customer's operation and maintenance tasks. Under this business model, most developers are fully responsible for the operation and maintenance. Therefore, the model reduces the customer’s technical and investment risk (ATW Solar, 2022; Xurya Solar, 2022). Lastly, the model immediately offers the benefit of electricity bill savings.

b. Key Partnership

Unlike the host-owned business model, the developers, as the third party, must have sufficient capital to fund projects. In the third-party-owned business model, the developers are responsible for most financing costs, such as upfront costs, operation costs and maintenance costs. To increase their capital, developers receive loans from lenders or investments from investors (Interviewee #1, 2022). Therefore, lenders (e.g., banks and financial institutions) and investors (e.g., venture capital) are crucial partners for the developers.

Another key partner is the utility company PLN. Similar to the host-owned business model, collaboration with PLN is crucial to ensure the grid connection process and permit approval (Interviewee #1, 2022). Another key partner is the EPC company, responsible for the installation, operation and maintenance. Lastly, the technology supplier and consultant are essential in ensuring the PV components and system quality. The following figure summarises the relationship between the key partner.

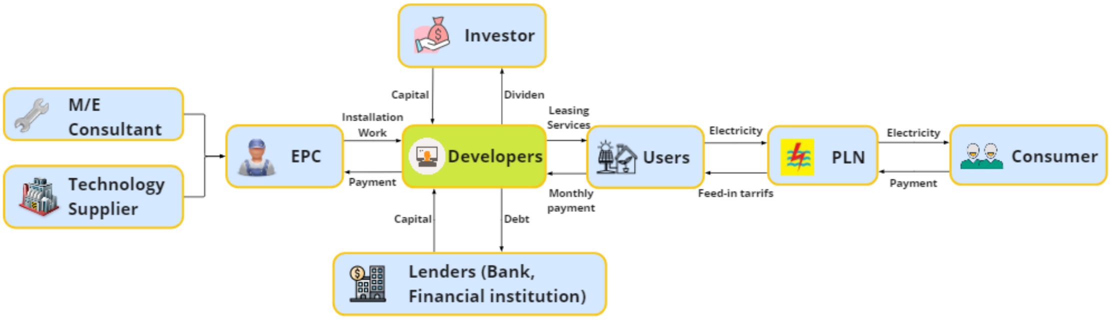

Figure 23 The structure of third-party-owned business model

c. Key Activities

The most common key activity in the third-party-owned model is a lease of the PV system. In the lease process, developers require fund management to arrange financing by collecting several projects and selling them to the investors or lenders (Horváth & Szabó, 2018). Like the host-owned model, most developers in Indonesia offer complete services to the customer, including installation, permit submission, and grid interconnection arrangement (Interviewee #1, 2022). In addition, companies also include monitoring, operation and maintenance tasks in the lease contract (ATW Solar, 2022; Xurya Solar, 2022). Lastly, marketing via several social media like Instagram is carried out by several developers.

d. Key Resources

The local market resources, including good relations with other stakeholders (e.g. government, suppliers and customers), is critical in broadening the network and ensuring the business's success. Secondly, due to the business model related to a complex and long-term management task, developers must have a project management and monitoring system to manage the projects comprehensively (Horváth & Szabó, 2018). In addition, well-trained employees such as financial and technical experts are essential to ensure the quality of the PV system.

e. Customer Relations

In the third-party-owned business model, the developer companies build long-term relationships with the customer through a lease contract. In general, the lease contract is valid for a long term of 20 years or 30 years, depending on the depreciation of the PV system value (Interviewee #1, 2022). Other customer relations are through direct and online communication, similar to the host-owned business model.

f. Customer Segments

Customer segmentation can be distinguished into two segments: industrial and residential segments. In Indonesia, the industrial sector is the primary customer in the third-party-owned business model (Interviewee #7, 2022).

g. Channels

A sales representative is the most common channel developers use to build relationships with potential customers. In this process, developers provide several information about the benefit of a third-owned business model (Horváth & Szabó, 2018). Moreover, most developers in Indonesia have a company website and social media such as Instagram, Facebook and WhatsApp as marketing tools to maintain customer relationships. Lastly, developers also attend several events, such as exhibitions, discussions, etc., to build relationships with manufacturers, government, other companies and users (Interviewee #2, 2022; Interviewee #8, 2022).

h. Cost Structure

Under the third-party-owned business model, the developers are responsible for the construction and the PV system installation. In this case, the construction cost is included in the cost structure. Secondly, unlike the host-owned business models, most of the expenses for developers are in leasing management, including the acquisition of public and private investors (Horváth & Szabó, 2018). In addition, the marketing cost is used to fund marketing activity. Lastly, the developers are responsible for complete services. Thus, the cost for repairs and maintenance is also included in the cost structure (Cai et al., 2019).

i. Revenue Streams

The majority of the revenue comes from the solar lease solution. Under the leasing contracts, the customer leases the equipment and uses the energy generated by the PV system. In this case, the revenue comes from monthly payments. The leasing fee can be organised into two payment options. The first option is a bulk payment which does not depend on the electricity used by the customer. Based on the lease agreement, the bulk payment is completed by the fixed cost (e.g., IDR/Month). The second payment method is performance-based rental payment calculated based on the electricity generation per kWh (e.g. IDR/kWh) (Interviewee #8, 2022). Other sources of income received by developers include loans from banks and investment capital by investors (Interviewee #1, 2022).

7.1.4. Cooperative Business Model

As outlined in the 1945 Indonesian Constitution, a cooperative is a joint business model that operates based on the principle of kinship (human society). The Village Cooperative Unit (KUD) was formed according to the Presidential Instruction in 1978 as a type of cooperative, consisting of several functions such as distributor, micro banking, trading, farming production and others (ICA, 2020).

The rooftop PV cooperative business model was implemented in a solar home system project for rural development and electrification in the 1990s. Following the demonstration project in Sukatani village, the KUD took the initiative to install 1500 units of solar home systems in Lebak, West Java. Lebak was the commercial introduction undertaken by the KUD (de Quay, 1994).

This section discusses a cooperative business model of KUD with a case study of solar home systems in Lebak, West Java. The cooperative business model is explained based on desk research. The following figure presents the business model canvas of cooperative.

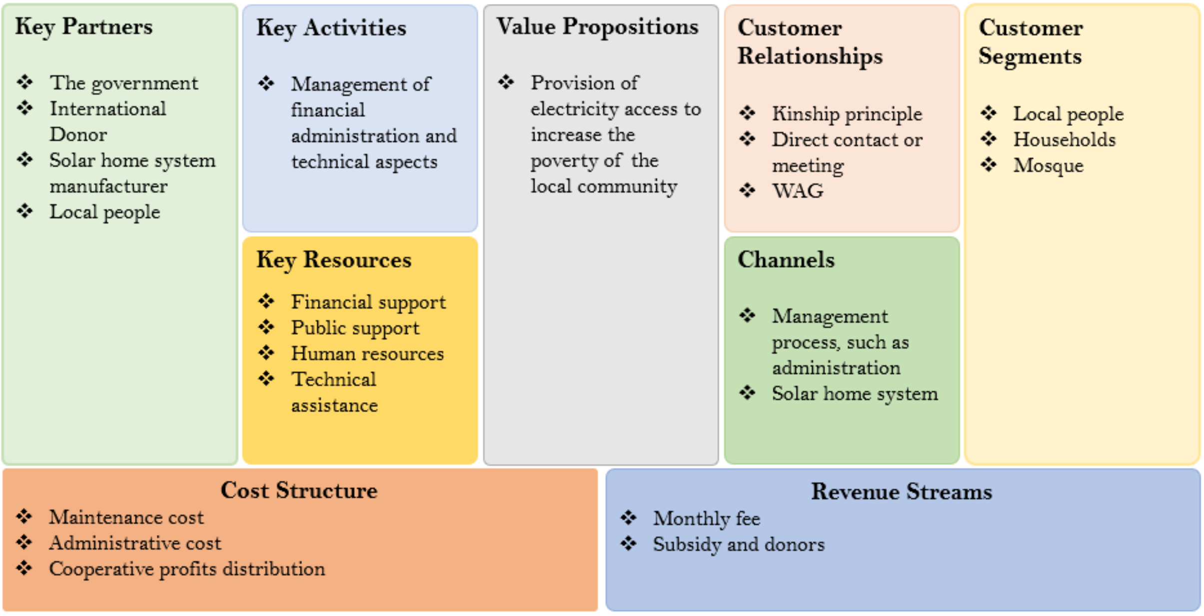

Figure 24 Cooperative business model canvas

a. Value Proposition

The KUD aims to increase the welfare of the local community, especially in rural areas, by supporting the local community's economic activities to meet current and future needs (ICA, 2020). Generally, the KUD mainly focuses on the agricultural sector to help farmers improve production results (Riswan et al., 2017). However, in the case of Lebak, KUD helped the local society by enabling access to the solar home system (de Quay, 1994).

b. Key Partnership

The key partnerships of KUD are the government, international donors, PV manufacturers, and the local community. In the 1990s, through Repelita V and VI, the government provide subsidies to increase solar home systems in rural areas (de Quay, 1994). International donors, such as World Bank and AusAID, provided financial support through the credit scheme. PV manufacturers were responsible for installation and training for local KUD. Meanwhile, the local community, the target of the cooperative movement, paid a monthly fee to the KUD (Nieuwenhout et al., 2000).

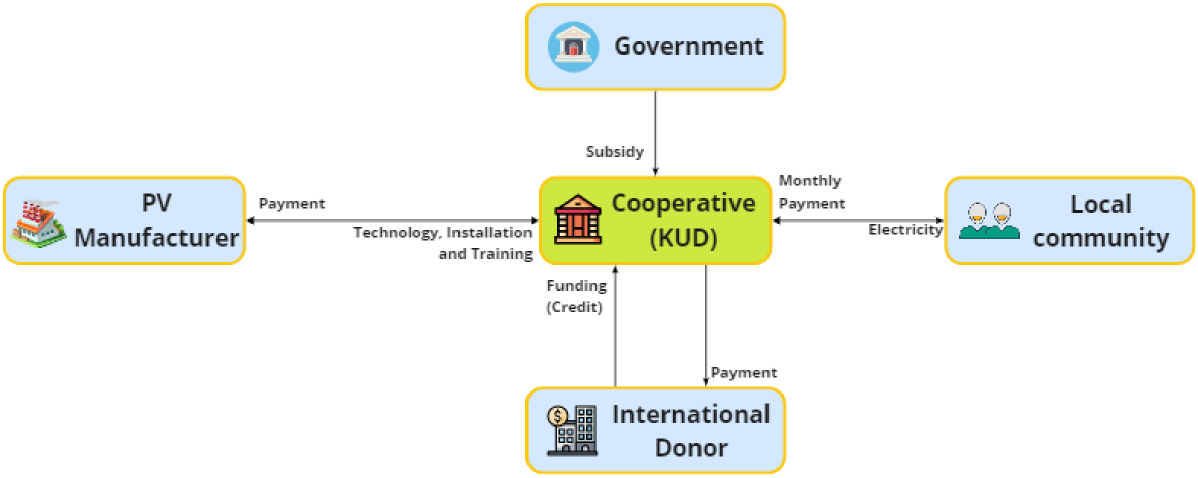

Figure 25 The structure of the cooperative business model

c. Key Activities

Acting as the intermediator, KUD established a new independent unit to arrange the financial and technical aspects of the solar home systems. The cooperative initiative conducted by KUD was essential to help the PV manufacturer (such as R&S company) handle the credit administration and elevate the user's position to have a better negotiation process (de Quay, 1994). The KUD also collected the monthly payment from the users. In terms of technical aspects, the KUD arranged the maintenance of the system and purchasing equipment such as new batteries and spare parts (Nieuwenhout et al., 2000).

d. Key Resources

Three essential resources that strengthen the cooperative business model of KUD are government support, financial support from donors, and public support through participation (Riswan et al., 2017). As explained previously, government support through policy and financial incentives was essential to support the KUD in rural solar home system diffusion. The financial support by the International donors through the credit scheme was also important in decreasing users' financial barriers (Nieuwenhout et al., 2000). Moreover, another critical resource is the public's active participation in the cooperative movement for the used solar home systems.

e. Customer Relations

Customer relations in cooperative business models are based on principles of kinship (human society) (ICA, 2020). The KUD maintain customer engagement through direct contact and meeting. Currently, KUD uses WhatsApp Group (WAG) to improve the interaction with the members and spread information about activities and products (Nurrachmi, 2020).

f. Customer Segments

The customer segment of KUD mainly focuses on the local villagers, especially local farmers in rural areas (Nieuwenhout et al., 2000). In the case of solar home systems in Lebak, KUD organised the diffusion of solar home systems in the local community, such as households and mosques (de Quay, 1994).

g. Channels

In delivering the electricity to local villagers, KUD, as an intermediator, formed an independent unit to supervise the management and administration of solar home systems. Moreover, the technology (solar home system) is another channel in delivering electricity to local communities (Nieuwenhout et al., 2000).

h. Cost Structure

The cost structure of KUD consists of three elements. First, because KUD was responsible for maintaining the systems, the maintenance cost (e.g., the cost of purchasing new batteries and spare parts) was borne by KUD. Second, the cost during the administration process was also included in the cost structure (Nieuwenhout et al., 2000). Lastly, the profit distribution to KUD members is also part of the cost structure. Generally, cooperative profits are in the form of operating profit (SHU) which are distributed to members based on the participation of each member (Nailufar, 2020).

i. Revenues Streams

The revenue streams of KUD come from the payment from customers. In case of Lebak, customer paid a monthly fee to KUD (Nieuwenhout et al., 2000). Other revenues are received from the government subsidy and international donors.

7.2 Analysis of business model roles in rooftop PV niche development

This section discusses how and to what extent the business models can overcome the barriers identified in Chapter 6. In table 17, two stars indicate that the business model can effectively overcome barriers, one star indicates that the business model can partly overcome the barriers, and without a star indicates that the business model is ineffective in solving the barriers.

Table 17 The extent to which three business models overcome identified barriers

Main Barriers	Host-owned Model	Third-party-owned (Leasing)	Third-party-owned Model (Rental)	Cooperative Model
Financial and Profitability Barrier	★	★	★	★★
Institutional Barriers				★★
Policy Barriers				
Technical Barriers	★	★★	★★	★★
Awareness Barriers	★	★	★	★★

In the case of financial and profitability, the cooperative model can overcome the barrier better than the other business models. With grants from the government and international donors, the cooperative model can overcome the financial obstacles by decreasing the upfront cost and reducing the long payback period. Moreover, the fixed monthly payment from the users ensures the companies' revenue stream without concerning the change in the electricity tariffs or net-metering scheme rates. Meanwhile, the absence of government incentives weighs on the financial and profitability of other business models. In the host-owned model, the potential users must pay a high initial fee which is one of the constraints of the host-owned model. However, the host-owned model offers a shorter payback period than the third-party-owned model. In contrast, the third-party-owned model (leasing and rental) eliminates the high upfront cost, which is the main value proposition of this model compared to other models. However, due to the lack of incentives, the payback period of the model is longer than others. In the rental scheme model, the revenue uncertainty issue cannot be overcome because the payment method depends on fluctuating generated electricity capacity, electricity tariffs and the net-metering scheme rate.

In terms of institutional barriers such as permits from PLN, limitations of capacity, and PLN revenue reduction, the cooperative business models might overcome the obstacles because the model mainly focuses on rural rather than urban areas. According to the public statements of PLN officials, the adoption of rooftop PV should be prioritised for the people who still experience power shortages, many of whom live outside Java (Hartomo, 2018). In line with this statement, the cooperative business model through KUD can be an alternative to widely adopting rooftop PV while helping PLN electrify rural areas. In this case, the cooperative business model can promote the rooftop PV without reducing the PLN revenue. And also, the permit issue and limitation of installed capacity barriers can be overcome.

The technical barriers such as the maintenance and installation issues can be overcome through the three business models. However, third-party-owned and cooperative models are more effective in solving the barrier than the host-owned model. Under the third-party-owned and cooperative models, the developers and KUD are fully responsible for maintenance and installation. In this case, the models eliminate the user task of operating and maintaining the system. In contrast, the host-owned model separately offers the maintenance service with an additional fee. The existence of maintenance costs will burden the user financially. Moreover, although the three models can overcome several technical obstacles, none of the business models seems to be an alternative solution to increase the local manufacturer's capability to comply with the local content policy (TKDN).

In case of awareness barriers, because of the close relationship (kinship principle) through the direct contact and WhatsApp group with the local people, the cooperative models by KUD can conduct an effective campaign to increase people's awareness of renewable energy development. Moreover, with access to almost all villages in Indonesia, the cooperative models by KUD can provide broader access for the government to educate the people compared to the other models. Meanwhile, the host-owned and third-party-owned model can raise public awareness through advertising and sales representatives.

However, both models require additional capital to cover advertising costs and salesperson salaries. Therefore, by increasing the renewable energy campaign, the cooperative model might become an effective alternative to overcome the low public awareness.

Finally, these three business models appear to have no influence on the obstacles in the policy sector. The three business models are ineffective in overcoming policy barriers such as inconsistent regulation and local content policy.. Table 18 summarises the extent to which the business models play a role in overcoming barriers.

Table 18 Summaries of business model roles overcome barriers

Main Barrier		**Host-Owned**	**Third-Party-owned (Lease)**	**Third-Party-owned (Rental)**	**Cooperative**
Financial Barrier	Revenue uncertainty	✓	✓	✗	✓
	Absence of government incentive	✗	✗	✗	✓
	High upfront cost	✗	✓	✓	✓
	Long payback period	✓	✗	✗	✓
Institutional Barrier	Permit from PLN	✗	✗	✗	✓
	Limitation of installed capacity	✗	✗	✗	✓
	PLN revenue reduction	✗	✗	✗	✓
Policy Barrier	Regulation inconsistency	✗	✗	✗	✗
	Local content regulation	✗	✗	✗	✗
Technical Barrier	Local manufacturer capability	✗	✗	✗	✗
	Maintenance and installation task	✓	✓	✓	✓
Awareness Barrier	Low awareness	✗	✗	✗	✓
	Limited campaign	✓	✓	✓	✓

7.3 Conclusion

Based on the business model canvas designed by Osterwalder et al. (2010), this chapter has identified in detail the characteristic of four types of the business model associated with rooftop PV niche development. The four business models are (1) the incumbent electricity operator business model, (2) the host-owned business model, (3) the third-party-owned business model, and (4) the cooperative business model. The following table summarises the value proposition, value creation, value delivery and value capture mechanism of each business model.

Table 19 Value proposition, value creation, value delivery and value capture mechanism of PV business model

Value	Incumbent	Host-Owned	Third-Party-Owned	Cooperative
Proposition	• Affordable, reliable, and accessible electricity service • Profitability • Comply with regulation	• Reduce electricity bill • Flexibility • Full benefit from feed-in-tariffs • Environmental protection	• No-upfront cost • Eliminate the technical and financial risk • Electricity bill saving • Environmental protection	• Provision of electricity access • Welfare of local villagers • Environmental protection
Creation	• Electricity generation, transmission, and distribution • Electricity sales • Maintenance	• Total services • PV system purchase • Repair and maintenance	• Lease and rental • Total services • System operation and maintenance	• Management of financial and technical aspects
Delivery	• Customer services • Online applications	• Salespeople • Advertisement • After-sales service • Online and offline contact	• Salespeople • Advertisement • Online and offline contact and promotion	• Administration • Maintenance • Direct contact or meeting • Online media
Capture	• Electricity sales • New system installation service • Government subsidies	• System sales • After-sales service • Installation, repairs and maintenance	• Lease and rental payment • Loan	• Monthly payment • Government subsidy • International donors

In general, the value proposition of all the business models is concentrated on the welfare of the users. In the case of the incumbent business model, the PLN aim to provide reliable and affordable electricity to all society in Indonesia. The host-owned and third-party-owned business model helps the customer to increase poverty by providing technology to reduce the electricity bill—meanwhile, the cooperative business model offers a service to enable electricity access to local villagers. Another shared value within the four business models is environmental protection. By providing access to rooftop PV, the host-owned model, the third-party-owned model, and the cooperative model are helping the community solve the climate change issue. In the case of the incumbent business model, with the increased percentage of renewable energy as the key resource, the PLN also contributes to protecting the environment from climate change.

This chapter also outlines how and to what extent the three business models can help to eliminate the identified barriers. First, the cooperative business model is analysed to be more effective in overcoming the financial, profitability, institutional, and awareness barriers in Indonesia than other models. The support of the government subsidies and international donors, access to almost all villages in Indonesia, and the value proposition to increase public poverty are the factors that enable the cooperative business model to overcome the barriers.

In contrast, the host-owned model is identified as the least effective business model for overcoming the identified bottlenecks. The absence of government incentives and high-up front costs prevent the host-owned model overcome these barriers. The third-owned-party (lease and rental) models, due to zero upfront cost and total solution service, are considered adequate to solve several bottlenecks, including technical barriers.

Furthermore, table 18 and table 19 also show the limitation of the identified business model in overcoming obstacles. The four business models are incapable of solving several barriers, such as the policy barriers regarding the regulation inconsistency and local content regulation, and technical obstacles regarding the local manufacturer capability.

CHAPTER 8 – DISCUSSION

8. 1. Inter dynamics between three levels

This chapter integrates two transition analysis frameworks, MLP and SNM, and nine-building blocks of the business models framework developed by Osterwalder et al. (2010). The MLP provides an inter dynamics analysis between three heuristic levels: the socio-technical landscape, the socio-technical regime and the niche innovation. The niche innovation process was analysed using the SNM framework with additional insights into landscape and regime factors from the MLP framework analysis. The SNM framework analyses three niche development processes: shielding, nurturing and empowerment. Lastly, the business models are added to the niche innovation as the catalysator for promoting the niche at the regime level.

The early development of rooftop PV at the end of the 1980s was firstly motivated by low electrification in rural areas as a landscape factor. The rural electrification factor created a window of opportunity for companies (in this case, R&S Renewable Energy System) to bring the innovation of solar home systems to Indonesia. R&S renewable company started the solar home system project by collaborating with a Dutch government agency, DGIS, and Indonesia government agencies, BPPT. The project began with the demonstration project in Sukatani village, West Java. The demonstration project also served as a learning process to fulfil the gaps between the market needs (require knowledge) and the technicality of the system (crucial expertise). During the project, the learning process (using the field survey and directly communicating with local villagers) was conducted by the DGIS and BPPT. The result of this learning process became the evaluation of the system. This learning process also informed the other actors about the project's achievement. After this process, the demonstration was successful despite several technical problems.

The low electrification ratio and the success of the solar home system pilot project created wider opportunities for rooftop PV niche development by putting pressure on the government. After the Sukatani project, the government launched two government initiatives: the president's financial incentive (Banpres) through the national development plan 'Repelita V' and the government's project called "Fifty Mega Watt peak Photovoltaic Rural Electrification" in Repelita VI. These two initiatives provided an active shielding space, which attracted more actors to be involved. Many stakeholders (e.g., world bank, AusAID, local bank, international suppliers, local suppliers, KUD, etc.) participated by providing funding (e.g., credit), technologies (e.g., battery, PV modules, cable, etc.) and innovative business model (e.g., cooperative and lease schemes). These participations and alignments between stakeholders nurtured the niche development.

However, the development of rooftop PV was de-accelerated by the financial crisis in 1997. The Asian Financial Crisis 1997-1998 is the next landscape factor that influenced the regime change and terminated the government inventive (due to the government change and termination of 'Repelita VI'). The turbulence in the financial and political sector also hampered the rural development project organised by the world bank due to high inflation, high-interest rates, etc. In this era, rural electrification project managed by the government was discontinued. Moreover, with the absence of government incentives and declined local participation (due to economic conditions), the cooperative business model seems to be affected and became dysfunctional. Due to the influence, the financial crisis as landscape factors became the setback momentum for rooftop PV niche development.

Since 2004 when Indonesia officially became a net importer country, energy dependency as a landscape factor has become another important issue in Indonesia's energy sector. This energy security issue created a new opportunity for renewable energy development by motivating the government to accelerate renewable energy development. As a result, in 2006, the government mandated the National Energy Policy (KEN), which stated 17% renewable energy by 2025 and 31% by 2030. This regulation seems to influence the formation of IESR, a non-governmental organisation that focuses on government advocacy and actively conducts knowledge transfer and community empowerment regarding renewable energy. Moreover, in 2013, the government launched the feed-in tariff (FiT) for the first time to support renewable energy. The FiT scheme motivated the use of rooftop PV in urban areas.

Growing awareness of climate change is another factor at the landscape level that pressures the regime government to develop renewable energy. In 2015, the government of Indonesia agreed to the Paris agreement and committed to reducing the emission. To achieve this goal, the government revised the national energy policy by set NDC to reduce GHG emissions by 29% (its effort) and 41% (with international support) by 2030. Moreover, the government relaunched fit-in-tariff mechanisms in 2015 and transformed them into the net metering mechanism in 2018. This NDC target and net metering mechanisms create a window of opportunity for the diffusion of rooftop PV. Many new start-ups, companies, and associations were formed. The new business model, the host-owned model, was also innovated.

International and market pressure on the industrial sector is a landscape factor that forces many industries to reduce GHG emissions. The ESG score launched by the UN in 2015 as a collaborative strategy motivates many actors, including investors and companies. The growing trend of ESG forced companies to renew business activities to achieve a higher ESG score. This factor created a new opportunity for niche actors to create a new business model, such as a third-party-owned (rental scheme) business model. Figure 26 presents the inter-dynamics of landscape, regime and niche.

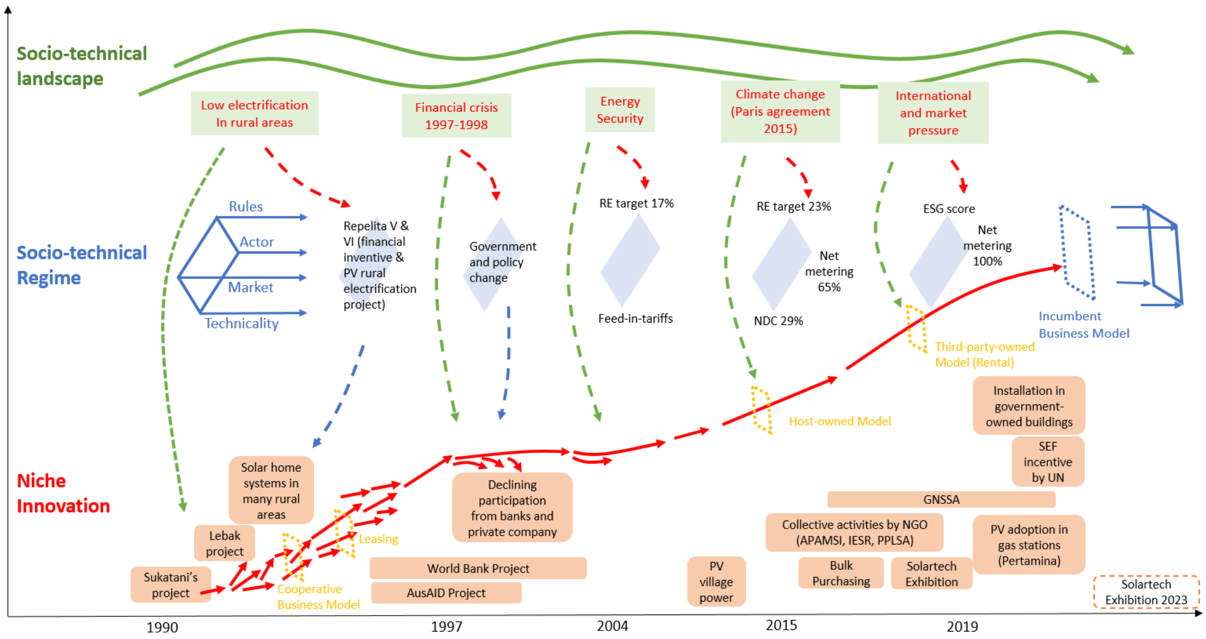

Figure 26 Integrated MLP, SNM, and business model framework for rooftop PV niche development in Indonesia (Adapted from Geels, 2002)

8. 2. The role of business models in the rooftop PV development in Indonesia

The sustainable business model framework analyses the activity conducted by niche and regime actors in the rooftop PV development. This thesis show three business models (besides the regime business model) of PV business actors: host-owned model, third-party owned model, and cooperative business model.

First, the private EPC companies are involved in rooftop PV development through the host-owned business model. This business model provides all services from installation, procurement, permit arrangement, repairment, and maintenance. This model allows customers to profit from the government's net metering scheme and reduce users' electricity bills. Unlike the third-party-owned business model, this model can also benefit from financial incentives provided by the international donor (UNDP) as a niche shielding space. Regarding the role of the business model, the host-owned model enables a new social network between users and lenders. The host-owned model facilitates alignments between stakeholders, such as loan and payment transactions. In addition, this business model shapes the actor's expectation by synchronising activity to achieve the 23% renewable energy target in 2025. To sum up, first, the host-owned business model is operated because of the window of opportunity offered by the feed-in-tariff mechanism by the regime actor, the government. Secondly, the niche shielding protection through financial incentives helps niche activity in this business model. Therefore, because this business model can synchronise various activities and support niche innovation, the host-owned business model has a role as an intermediate between technological niche and regime, as stated by Bidmon & Knab (2018).

The third-party-owned business model by developers eliminates several financial barriers, such as high up-front costs, which increases the economic benefits of rooftop PV. In this model, developer companies must have sufficient capital to fund the project. Capital investors and lenders such as banks play a role in providing funds for developer companies. Moreover, this business model eliminates several user technical barriers by overtaking operation and maintenance tasks. The generated electricity is transferred and sold to the PLN under the net metering scheme. This show that the net metering scheme provides an opportunity for a new business model like the this-party-owned business model. The revenue stream of this business model is distinguished into two payment options: leasing and rental schemes. Because this model eliminates two barriers between niche and regime and supports the collaboration between many actors in social networks, the third-party-owned business model fits with the business model's characteristic as intermediates between niche and socio-technical regime formulated by Bidmon & Knab (2018). However, problems such as permits and limitations of installed capacity can reduce the opportunity offered by the third-party-owned business model.

The third business model associated with PV business activities is the cooperative business model. The cooperative business model existed during the early adoption of the solar home system in the 1990s. However, due to the financial crisis, the role of cooperatives gradually declined. Although the cooperative model was implemented for rooftop PV, the analysis shows that this business model is more effective in overcoming financial, institutional, technical, and awareness barriers. The value proposition of this model is to increase the welfare of rural communities by providing access to electricity. The key activity is to become the intermediator to manage the financial and technical aspects of the system. This business model enables the alignment between local villagers, PV manufacturers and banks. The primary source of income is from government incentives and international donors. Therefore, due to the dependency on government and international donors, the business model declined during the financial crisis. To sum up, the cooperative business model complies with the characteristic of an intermediator between niche and regime described by Bidmon & Knab (2018).

8. 3. Academic contribution

The academic contribution of this study mainly lies in the integration of the business model framework into SNM and MLP. Although many studies on analysing sustainable transition use SNM and MLP frameworks, only a few researchers have integrated the business model frameworks into SNM and MLP. Only one research conducted by Hakim (2021) has been found to integrate a business models framework into SNM and MLP. According to Hakim (2021), more studies need to be conducted on integrating these three frameworks. Moreover, a recent study by Elmustapha & Hoppe (2020) also suggested a need for future research studying the addition of business models to the SNM framework, especially in the case of developing countries. This study attempts to fulfil this knowledge gap and study the integration of the business model framework to the SNM and MLP in niche development. The integration of business models, SNM and MLP framework, enables this study provides rich empirical data on rooftop PV development in Indonesia. In addition, by integrating the business models into SNM, this thesis attempts to provide additional insights into the learning process associated with the business models developed by Kamp & Vanheule (2015). Therefore, the contribution academic of this thesis abides in a more extensive integration between the business model framework and sustainability transition framework (SNM and MLP).

The number of works of literature studying the SNM framework application in developing countries is limited (Romijn et al., 2010; Wieczorek, 2018; Xue et al., 2016). Therefore, this thesis also contributes to providing a case study of sustainable transition in developing countries by adopting the SNM framework of shielding, nurturing, and empowerment.

Furthermore, Langer et al. (2021) argued that lack of publication is one of the research gaps for Indonesia to achieve its renewable energy potential. This thesis also contributes to adding a new publication associated with Indonesia's cases, especially adding literature on SNM framework application in Indonesia.

Another contribution that can be added by this thesis is related to the new perspective of SNM frameworks. Several studies, such as Rehman et al. (2010), argued that branding, marketing and a financial loan from a bank are essential aspects of India's PV lighting technology niche development. Elmustapha et al. (2018) discovered the importance of multinational support (e.g., international donors) in disseminating new technology in developing countries. In line with these statements, this thesis also finds that International donors (e.g., World Bank and AusAID) and financial loans are essential in the rooftop PV diffusion. As an additional perspective to the SNM framework, this thesis found that the role of associations (e.g., IESR, AESI, PPLSA, APAMSI, etc.) is essential in rooftop PV niche development in Indonesia. Their roles in providing knowledge transfers, public education, and government advocation enable the alignment between the multiple stakeholders and influence the actor's expectations.

In addition to the MLP frameworks, the case study of rooftop PV niche development in Indonesia can add a new important landscape factor that pertains to the 'market and international pressure'. Many researchers argue that landscape factors such as demographic shift, macroeconomic conditions, wars, natural disasters, and wars pressure the regime (Geels, 2002; Schot & Geels, 2008; Smith & Raven, 2012). In Indonesia's case, pressure from the market and International society on the industrial sector force many industries to adopt rooftop PV.

In the last 30 years, the publication on rooftop PV development has been distinguished into two types of publication. The first type of publication studies the early solar home system development during the 1980s-1990s. Meanwhile, the second type of publication explains the current rooftop PV development in the 2000s (e.g., potential energy study, market willingness, business model, etc.). However, no study has explained and combined the rooftop PV niche development process from the 1980s until 2022. The only available research that presents the innovation of rooftop PV from the 1980s until the 1990s was presented by de Quay (1994). Therefore, as another contribution, this thesis attempts to integrate the entire development process and thoroughly explains the niche development of rooftop PV from the 1980s (the first project of rooftop PV) until the current development using a historical schematic MLP diagram.

8. 4. Practical Contribution

The practical contribution to policymakers is that this thesis provides information to understand the factors, including regulation, that have influenced rooftop PV development. This thesis shows that frequent regulation changes create uncertainty among the business players. Although the current policy changes are more supportive (increased net-metering tariffs to 100%, etc.), most business actors consider the new regulations slowing the previous rooftop PV development. Therefore, the government should manage the expectation by providing clarity and consistency in policy. Another factor is regarding the local-content policy. Because local manufacturers are currently incapable of producing good quality and low price products, the PV providers view this policy as a barrier to their finance. Therefore, the government should adjust the local content policy based on the local manufacturer's capability and PV provider's conditions. This could be done by conducting hearings and discussions with various related actors. Other factors are subsidies and international donors. The thesis shows the importance of grants and international donors in maintaining the rooftop PV development. Maintaining the subsidies and inviting international donors is essential to give protection for rooftop PV development.

The practical contribution to niche actors is to understand the barriers, opportunities, and contributions of the business model in developing rooftop PV. This thesis found that low public awareness and lack of campaign are obstacles to rooftop PV niche development. Therefore, the business actors should conduct campaign activities to improve public awareness.

CHAPTER 9 – CONCLUSION AND RECOMMENDATION

9.1. Conclusion

The answer to the sub-research question and main research question is provided based on the findings discussed in the previous section.

a. SQ1: What are the main actors and factors influence rooftop PV development in Indonesia?

In the early 1990s, rooftop PV was initially used in the solar home system in rural areas. Rural development and electrification factors motivated a private company (R&S), an international government agency (DGIS), and a local government agency (BPPT) to collaborate to develop the solar home system. Rooftop PV development started with a solar home system pilot project in Sukatani village. After the success of the Sukatani project, the government of Indonesia wanted to utilise the solar home system as a solution to the rural electrification problem. Through five-year national development, 'Repelita V' and 'Repelita VI', the government launched financial incentives and a project called "Fifty MWp Photovoltaic Rural Electrification". These regulations created opportunities for non-governmental organisations to participate. Several NGOs, such as World Bank and AusAID, launched funding support (e.g., credit). Moreover, other organisations (e.g., local suppliers, International suppliers, KUD) played roles in technical aspects and management aspects.

The second factor influencing rooftop PV was the Asian Financial crisis in 1998. First, the financial crisis led to the resignation of the Soeharto regime in 1998. The government change in 1998 caused the termination of national project development plans 'Repelita VI', which included the solar home system initiative 'Fifty MWp Photovoltaic Rural Electrification.' Secondly, the financial crisis created turbulence in Indonesia's economic sectors, such as the 80% devaluation of the currency, the 43.2% downfall of GDP, high inflation, high-interest rates and uncertainty of the future. This turbulence demotivated the consumer to use a loan from the bank for PV installation. Moreover, the financial crisis prevented financial institutions such as banks from providing loans to solar system suppliers.

Climate change and energy security issues at the landscape levels also influence the energy sector in Indonesia. Climate change and energy security affected the national energy policy (KEN), which resulted in the announcement of Indonesia's NDC goals of 23% renewable energy in 2025, 29% GHG reduction by 2030 and net-zero emission in 2060. Moreover, these factors motivated the government to provide incentives and policies like a net metering scheme to support the PV installation.

Lastly, the International and market pressure on the commercial and industrial sector force them to use rooftop PV to increase the ESG score of the company. In this case, the market is growing due to the increasing demand from the industrial sector.

b. SQ2: What are the main barriers and opportunities to rooftop PV in Indonesia?

The niche development of rooftop PV in Indonesia faces several obstacles, including financial, institutional, policy, technical, and awareness barriers. Based on the interview, private companies, such as developers and EPC companies, face financial challenges such as revenue uncertainty and the absence of government incentives. The developers are currently forced to sell a product at a low price (e.g. 10-20% lower than the electricity price) which reduces the company's revenue. Furthermore, financial barriers are also faced by the users. The user representatives stated that at the current rooftop PV price and low net metering fee, the user would receive a long payback period for its investment. This factor demotivates users from using rooftop PV.

Another issue is related to institutional barriers that are mainly related to PLN. Several problems, such as permits issue from PLN, capacity limitation, and PLN hesitancy due to revenue reduction, are currently hindering the diffusion of rooftop PV. Several interviewees consider these institutional barriers as the main barriers to rooftop PV development.

Another obstacle is related to the policy. Regulatory changes that the government often conducts create uncertainty among business actors. Moreover, the new local content policy issued in 2021 hinders rooftop PV diffusion. The higher price of locally produced components decreases the benefit that can be achieved by business actors. Lastly, the implementation of local content seems did not base on the current local supplier's ability. Currently, the local suppliers are incapable of complying with the local content policy.

On the other hand, the development of rooftop PV in Indonesia is promising because of the enormous solar resources and some government-support policies. According to the government, Indonesia, an archipelago country that lies across the equator, has massive solar resources (208 GW). Considering the tiny application of solar resources, Indonesia still has a lot of potential for future growth. Lastly, the supportive policy issued by the government, such as the net metering scheme and financial incentives, boosts the rooftop PV diffusion.

c. SQ3: What type of business models are applied and how has it influenced the rooftop PV in Indonesia?

From 1990 (the early development of rooftop PV) until 2022 (present), three business model was identified in the niche innovation space of rooftop PV: cooperative business model, host-owned business model, and third-party-owned business model.

In the early commercial phase of the solar home system in the 1990s, many international donors and development agencies collaborated with the local counterparts to provide the financial and technical aspects to utilise the solar home system in many residential houses. The collaboration was accommodated by an organisation, namely the cooperative unit village (KUD), through the cooperative business model. A cooperative is a joint business model based on the kinship (human society) principle. The cooperative model aimed to increase the welfare of the local community in rural areas by enabling access to the rooftop PV. This model acts as an intermediary between several business actors, such as PV providers, banks and users. The main activities were to help the financial aspect by managing the credit administration and the technical aspects such as maintenance and spare part procurement.

The second business model is the host-owned business model. The host-owned model is the business model where the user has ownership of the installed rooftop PV system. This model enables users to benefit from the net metering mechanism and financial incentives launched by the government and international donors in the 2010s. This business model also provides a space for forming a social network between various actors. Several vital actors such as suppliers, lenders, users, and PLN form alignment in this business model. Those alignments are sell-purchase transactions and installation services between EPC and users, technology procurement between EPC and manufacturers, and credit transactions between users and lenders. Moreover, this business model can overcome barriers in niche development such as company revenue uncertainty, long payback period barriers, maintenance and installation task, and limited campaign issue. To conclude, the host-owned business model plays a role as an intermediator between niche and regime because this model enables access for users to benefit from the net metering scheme (as a government shielding strategy), provides a space to form a new network alliance (nurture the niche activities), and solves several obstacles between niche and regime level.

The following business model is a third-party-owned business model, usually arranged by a third party, the developers. In contrast to the host-owned business model, the developer owns and operates the rooftop PV system in the third-party-owned business model. This business model offers several benefits. The first benefit is that it eliminates rooftop PV installation's high up-front cost barriers. ‘No upfront cost’ is the main value proposition that differentiates this model from the host-owned models. The second benefit is that it removes the technical barriers from the user’s side. In this model, users do not need to perform the operation and maintenance tasks. In addition, the business model also provides a space for actors’ network alignments. This business model involves actors such as EPC, lenders, suppliers, users, and PLN. In summary, the third-party-owned business model acts as an intermediary between niche and regime landscape as it provides solutions to overcome barriers such as high up-front costs and users’ technicality issues. Moreover, the third-party-owned models contribute to more social niche activity by enabling different actors to interact and form a new network within niche space.

d. SQ4: How can the niche market of rooftop PV in Indonesia be developed?

Considering several blocking mechanisms from the incumbent electricity operator regime, the strategy to protect the rooftop niche should be continuously utilised. Active shielding through financial incentives, international donors, and net metering schemes can protect the rooftop PV niche innovation from the competition from the incumbent regime. Active shielding should be maintained to protect the rooftop PV niche development. Another strategy that needs to be considered is passive shielding. The passive shielding-like installation in a government-owned building that government currently plan can defend the rooftop PV. The execution of this passive shielding should be accelerated to provide a protective space for developing rooftop PV. Another strategy is related to the cooperative business model. The government or private sector should consider revitalising the cooperative business model in developing rooftop PV. This cooperative model can facilitate rooftop PV development in rural areas as a protected space.

Secondly, according to the SNM analysis, the expectation of niche actors on rooftop PV development is optimistic mainly due to the market growing demand and abundant solar energy sources. However, some actors expressed doubt about the future rooftop PV development due to a lack of clarity related to regulation (due to frequently change) and the implementation inconsistency of regulation (due to institutional barriers by PLN). Therefore, managing the niche-actors expectation should be considered by the government. Several actions, such as providing a clear regulation and guidance (e.g., long-term road map of rooftop PV development), socialisation and subsidies, can influence the niche actors' expectations.

One of the policies that could be revised is a local content policy that associates with the use of the local component. The incapability of local manufacturers to meet the 60% local content policy and higher prices of local components hinder niche diffusion. Therefore, the local content policy needs to be adjusted based on the capability of the local manufacturer (46% local content). Meanwhile, the shielding process to protect the local manufacturers from the imported product can be appropriate. The shield could be performed actively and passively. The active shield through financial inventive to the local supplier could be implemented. Passive protection, such as providing specific projects, should be considered.

Lastly, the rooftop PV development can be accelerated when the electricity market is liberalised. With the monopoly electricity sector in Indonesia, the development of rooftop PV is highly dependent on only one actor, the regime PLN. According to SNM analysis, the current development of rooftop PV is mainly blocked by institutional barriers (e.g., permit approval issues and limitation of installed capacity by PLN). Liberalising the electricity sector in Indonesia may enable easier access for consumers to become prosumers since the retail consumers can choose from which company to purchase or sell electricity.

e. MQ: How has the rooftop PV niche developed in Indonesia, and to what extent to business model influence niche development?"

The development of rooftop PV in Indonesia started at the end of the 1980s due to the low electrification ratio that motivated the private company to bring solar home system innovation to Indonesia. The demonstration project was implemented by the collaboration of three organisations: a private company (R&S renewable energy), a Dutch government agency (DGIS) and an Indonesian government agency (BPPT). The successful demonstration project in Sukatani attracted the President to be involved in niche development. The government then the financial incentive and national movement that encouraged international donors and development agencies to provide funding and technical assistance for developing rooftop PV in rural areas. The Asian Financial crisis in 1998 created pressures on regime actors, resulting in the financial issue and government changes which led to the termination of government policy and support for niche development. The financial crisis also put pressure on niche actors due to increased interest rates and higher PV modules that demotivate people and suppliers. The rooftop PV niche development was re-established after the announcement of a renewable energy target of 23% and the feed-in-tariffs mechanism. Moreover, the rooftop PV diffusion is expected to accelerate with a 100% net metering scheme. Lastly, the growth of pressure in the industrial sector encourages the diffusion of rooftop PV in industry.

The commercialisation of rooftops started in the 1990s after the government launched a government initiative for solar home system applications. The cooperative business model by KUD appeared in response to the high participation of many international donors and suppliers in the solar home system. The cooperative business model facilitated the collaboration of various stakeholders by taking the role of intermediator. Meanwhile, the host-owned model enables the user to use rooftop PV while at the same time benefiting from the net-metering tariffs and international incentives. However, the problem of high-up-front costs becomes the financial barrier to the host-owned business model. The third-party-owned business model is a solution to the high-up-front cost barriers. This business model offers rooftop PV installation with zero initial cost.

9.2. Recommendation

This thesis has presented the importance of shielding strategies in sustaining the rooftop PV niche development in Indonesia. Therefore, this thesis recommends the government to systematically consider and use the concept of shielding strategy during the approach and regulation formulation, especially in the energy sector.

To maintain the momentum of rooftop PV development, two shield processes need to be considered, which are active and passive. The active shield process, which directly influences niche innovation development, can be performed in several ways, including financial incentives, international donors and policy (e.g., net metering scheme). Considering many factors blocking the rooftop PV diffusion, this thesis recommends the government to continuously implement active shielding to protect the rooftop PV niche development. This shield strategy might also be used to manage and increase the positive expectation among actors. In addition, another strategy that needs to be considered is passive shielding, such as rooftop PV installation movement in a government-owned building. This thesis recommends the government accelerate the execution to provide a protective space for developing rooftop PV. Another strategy is related to the cooperative business model in KUD. Considering this business model's capability to overcome several barriers (financial, institutional, technical and awareness barriers), the government should consider revitalising the cooperative business model in developing rooftop PV. Providing financial and technical assistance to rural villagers through KUD can facilitate rooftop PV development in rural areas as a protected space.

The following procedure was created based on the interview and previously explained barriers.

1. To increase the economic competitiveness and reduce the payback period of rooftop PV, the Government of Indonesia should reduce subsidies on fuel resources and provide subsidies to rooftop PV business actors. The grants can be implemented through a tax deduction or capital.
2. Because the lack of clarity on regulation creates uncertainty in the rooftop PV market, the Government of Indonesia must systematically design the long-term road map of rooftop PV without frequently changing it. This might provide certainty among the market actors.
3. To accelerate the use of rooftop PV, the government should adjust the local content policy. For example, the level of local content can be reduced to 45%, which meets with the current local manufacturing capability.
4. To increase the public's awareness of renewable energy, the government must consider improving the campaign activity. The government might disseminate renewable energy information through community association networks (or *Rukun Tetangga/Rukun Warga*), television and newspaper (Setyawati, 2020)
5. The current passive building provided by the government should be implemented. The policy of building rooftop PV in the government-owned building needs to be organised in collaboration with the private sector through Private Public partnerships. The private-public partnership business model should be considered to provide finance for this project.
6. Lastly, to improve renewable energy diffusion, the development of the electricity sector toward liberalisation should be considered. Although it is hard to implement due to the regulation, the government might gradually introduce liberalisation to the electricity sector.
7. For business actors such as developers, business models applied in other countries such as community-based business models, roof rental business models or energy management contracts (EMC) need to be studied and considered.

9.3. Limitations and further research

Due to limited respondents willing to be interviewed, the business model case study does not fully cover the entire rooftop PV business ecosystems. This study has not covered several other business models, such as local banks and venture capital. Moreover, this thesis did not cover several actors' expectations, such as banks. Therefore, it is recommended for further research to have more respondents to gain in-depth information regarding the business model.

Secondly, the MLP, SNM and business model analysis on the early development of rooftop PV (the 1980s-2000) is conducted only through desk research. This led the researcher to spend much time finding related literature and analysis with limited sources. The cause of the lack of respondents who have experience in the early rooftop PV development was that the principal researcher did not analyse the history of rooftop PV in the initial stage of the research. This led to the selection bias of the interviewee. Therefore, it is recommended for further research on MLP and SNM to do some research on the history of the technology in the initial stage before continuing to the interview or analysis process.

Third, the case study results in this thesis were validated through several strategies such as conducting a broad cross-section of the interviewee, using the case study protocol and applying the analytical framework (Yin, 2014). However, this caused the case study to have limited generalizability of findings. For further research, another research method is recommended to increase the generalizability of results, such as a focus group discussion where the validation can be done.

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APPENDIX A. QUESTION LIST - INTERVIEW

Introduction

1. Please tell me about yourself or your organisation and your organisation's experience with rooftop PV?
   (*Tolong ceritakan tentang diri Anda atau organisasi Anda, dan pengalaman organisasi Anda dengan PLTS atap?*)
2. Why did you or your organisation decide to get involved in the development of rooftop PV?
   (Mengapa Anda atau organisasi Anda memutuskan untuk terlibat dalam pengembangan PV atap?)

Development of rooftop PV, Landscape, and Regime

3. What are the main developments about rooftop PV in Indonesia?
   (*Apa perkembangan utama yang berhubungan dengan PLTS atap di Indonesia?*)
4. What are the main factors and developments outside the rooftop PV sector influencing the development of rooftop PV in Indonesia (e.g. at the national level, international level, or the level of the electricity system? Would you expect changes in these developments and factors?
   (*Apa faktor dan perkembangan utama di luar PLTS atap yang mempengaruhi perkembangan PV atap di Indonesia (misalnya di tingkat nasional, international, atau tingkat sistem kelistrikan)? Apakah Anda mengharapkan adanya perubahan dalam faktor dan perkembangan tersebut?*)
5. Related to the previous question, what do you think about factors such as climate change, economics, and political circumstances in influencing the use of rooftop PV? Could it be a barrier or an opportunity to develop rooftop PV?
   (*Berhubungan dengan pertanyaan sebelumnya,* bagaimana *pendapat anda mengeai factor-faktor seperti perubahan iklim, ekonomi, dan keadaan politik dalam mempengaruhi penggunaan PLTS atap? Bisakah itu menjadi penghalang atau peluang untuk mengembangkan PLTS atap?)*

Articulation and shaping of expectation

6. What are your expectations for rooftop PV in Indonesia? How widely will it be developed and further implemented?
   (*Apa harapan Anda mengenai PLTS atap di Indonesia? Seberapa luas itu akan dikembangkan dan di implementasikan?)*
7. Have your expectations for rooftop PV changed over time, and how/why?
   (*Apakah harapan Anda untuk PLTS atap sama/berubah dari waktu ke waktu, dan mengapa?)*

Social networks formation

8. Who are the main actors in the development and implementation of rooftop PV in Indonesia, and why? What is their role?
   (*Siapa aktor utama dalam pengembangan dan implementasi PLTS atap di Indonesia, dan mengapa? Apa peran mereka?*)
9. What kind of organisation do you collaborate with? And what is their role in the development of rooftop PV?

(*Dengan organisasi apa Anda bekerja sama? Dan apa peran mereka dalam pengembangan PLTS atap?*)

10. Did you encounter any challenges collaborating or coordinating with other organisations? How to overcome these challenges?
    (*Apakah Anda menemukan kendala dalam kerjasama atau koordinasi dengan organisasi lain? Bagaimana mengatasi kendala tersebut?*)

Learning process

11. What activities did you participate in to increase your knowledge about rooftop PV? (e.g. seminar or workshop related to technical, policy, industry, social impact, environmental sustainability and organisation)
    (*Kegiatan apa yang Anda pernah ikuti untuk menambah pengetahuan Anda tentang PLTS atap? Misalnya seminar atau workshop tentang teknis, kebijakan, industry, dampak social, pelestarian lingkungan dan organisasi?*)
12. What have you learnt from your engagement on rooftop PV? (e.g. policy, regulation, laws, socio-cultural, technological, financial, market?)
    (*Apa yang Anda pelajari dari keterlibatan Anda di PLTS atap? (misalnya kebijakan, peraturan, undang-undang, social budaya, teknologi, keuangan, pasar?)*)
13. What activities are currently being conducted to increase the public knowledge and awareness about rooftop PV? (e.g. seminar, exhibition, event)
    (*Kegiatan apa yang saat ini dilakukan untuk meningkatkan pengetahuan dan kepedulian masyarakat tentang PLTS atap? (contohnya seminar, pameran dan acara yang lainnya)*)

Barriers and opportunities

14. What are the main barriers to rooftop PV development? (e.g. regulation, technology, price, market, culture)
    (*Apa hambatan utama dalam pengembangan PLTS atap di Indonesia? Misalnya regulasi yang tidak mendukung, akses kepada teknologi, pasar dan harga*)
15. What factor do you think are the opportunities that can drive the adoption of rooftop PV? (*Faktor-faktor apa yang menurut anda menjadi peluang yang dapat mendorong penggunaan PLTS atap?*)

Business model (for business actors)

16. Could you explain to me your business work? (e.g. main activities, value proposition, supply chain, revenue streams, resources, and partnership)
    (*Bisakah Anda menjelaskan kepada saya mengenai model bisnis anda?*)
17. In your opinion, what are the main factors that make your business work successful?
    (*Menurut anda, faktor utama apa saja yang membuat usaha anda berhasil?*)
18. What other business models do you think could work for or accelerate the diffusion of rooftop PV?
    (*Apa model bisnis lain yang menurut anda dapat berguna secara baik dan dapat mempercepat difusi PLTS atap?*)
19. According to you, is the current business model of the grid company accelerating or slowing the development of rooftop PV? And why?

(*Menurut anda, apakah model bisnis perusahaan jaringan listrik saat ini mempercepat atau memperlambat pengembangan PLTS atap? Dan mengapa?*)

20. How do current regulations and policies stimulate or limit your business model? And what do you think can be done to improve these regulations and policies?
(*Bagaimana peraturan dan kebijakan saat ini mendukung atau membatasi model bisnis Anda? Dan menurut Anda, apa yang bisa dilakukan untuk memperbaiki regulasi dan kebijakan ini?)*

Business model (for non-business actors)

21. What measures and actions would be needed to accelerate the implementation of rooftop PV in Indonesia? (The action could be conducted by (i) government, (ii) companies, (iii) citizens and civil society, and (iv) researcher or university)
(Tidakan apa yang diperlukan untuk mempercepat implementasi PV atap di Indonesia? Tindakan tersebut dapat dilakukan oleh (i) pemerintah, (ii) perusahaan, (iii) masyarakat sipil dan (iv) peneliti atau universitas)

The concluding question

22. Is there additional information you might want to share regarding rooftop PV development that has not been covered?
(*Apakah ada informasi tambahan yang ingin Anda bagikan mengenai pengembangan PLTS atap yang belum di bahas?*)

23. Do you have any recommended interviewees for further interviews?
(*Apakah Anda memiliki rekomendasi narasumber untuk diwawancarai?*)

APPENDIX B. INFORMED CONSENT

Informed Consent of Participant Information – Research on Rooftop PV in Indonesia

Research Title : Rooftop PV Development in Indonesia, A Niche Development Analysis
Researcher : Riando Hotasi Sirait
Affiliation : Delft University of Technology
Email : RiandoHotasiSirait@student.tudelft.nl
Supervisor : Dr. Jaco Quist

Purpose of Research

Thank you for taking the time to be interviewed as part of a research study titled "Rooftop PV development in Indonesia". The study is being done by Riando Hotasi Sirait from the TU Delft. The first objective of this research study is to investigate the development of rooftop PV in Indonesia regarding the actors' expectations of rooftop PV, actors' learning process, and the social network within actors in Indonesia's rooftop PV development. The second objective of this research study is to investigate the role of the business model in the transition of rooftop PV in Indonesia. In the end, the research will provide a recommendation to boost the development of rooftop PV in Indonesia.

Tujuan Penelitian

Terima kasih sudah bersedia meluangkan waktu menjadi narasumber dalam studi penelitian yang berjudul "Pengembangan solar panel atap di Indonesia". Studi ini dilakukan oleh Riando Hotasi Sirait dari TU Delft. Tujuan pertama dari studi penelitian ini adalah untuk mengetahui perkembangan solar panel atap di Indonesia yang berhubungan dengan expektasi aktor, proses pembelajaran dan interaksi sosial antar aktor didalam pengembangan solar panel atap Indonesia. Pada akhirnya, penelitian ini diharapkan dapat memberikan rekomendasi untuk mendorong pengembangan solar panel atap di Indonesia.

Data collection

The data collection will be conducted through an online video interview, which will be recorded. The data collection will take you approximately 45-60 minutes to complete. 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.

Metode pengambilan data

Pengambilan data akan dilakukan melalui wawancara video online, dimana video wawancara akan direkam. Pengambilan data akan memakan waktu sekitar 40-60 menit. Partisipasi Bapak/Ibu dalam penelitian ini bersifat sukarela, dan Bapak/Ibu berhak untuk menghentikan wawancara atau membatalkan kapan saja.

Data handling

As with any online activity, the risk of a breach is always possible. Your answer in this study will remain confidential to the best of our ability. Only the author will have access to the interview recording. And the interview recording will be deleted 1 month after finishing the project. Data regarding your personal data will be anonymised and will not be shared. The transcript of the interview will be stored in protected TU Delft one drive for 5 years (until August 2027). If the transcript is used for future work after 5 years, a representative from TU Delft will contact and request your permission.

Penanganan data

Seperti halnya aktivitas online lainnya, resiko pelanggaran selalu mungkin terjadi. Jawaban dari Bapak/Ibu akan kami jaga kerahasiannya. Hanya penulis yang akan memiliki akses ke rekaman wawancara. Rekaman video akan dihapus 1 (satu) bulan setelah penelitian selesai. Data mengenai data pribadi anda akan dianonimkan dan tidak akan dibagikan. Transkrip wawancara akan disimpan di TU Delft one drive yang dilindungi selama 5 tahun (sampai Agustus 2027). Jika transkrip digunakan untuk riset dimasa mendatang setelah 5 tahun, perwakilan dari TU Delft akan menghubungi dan meminta izin anda.

Explicit Consent Points – Research on Rooftop PV in Indonesia

	Yes *Iya*	No *Tidak*
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION ***A: Persetujuan Umum – Tujuan Penelitian, Peran Peserta dan Kebersediaan berpartisipasi***		
1. I have read the information regarding this study above, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction. 1. *Saya telah membaca informasi diatas mengenai studi ini, atau yang telah dibacakan kepada saya. Saya dapat mengajukan pertanyaan mengenai penelitian ini dan pertanyaan saya telah dijawab secara jelas.*	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason. 2. *Saya setuju untuk menjadi narasumber pada penilitian. Saya mengerti bahwa saya memiliki hak untuk menolak menjawab pertanyaan dan dapat mengundurkan diri dari penelitian kapanpun tanpa harus memberikan alasan.*	☐	☐
3. I understand that taking part in the study involves: a video-recorded interview and the interview will be transcribed as text. *3. Saya mengetahui jika penelitian ini meliputi: rekaman video dalam wawancara dan wawancara akan ditranskripsikan sebagai teks*	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION) ***B: Potensi Resiko Dalam Berpartisipasi (Termasuk Hal Proteksi Data)***		
4. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) such as name, organisation name and job title with the potential risk of my identity being revealed. The research will mitigate the potential risk of a data breach using the TU Delft system. *4. Saya mengetahui jika dalam berpartisipasi dalam studi akan meliputi pengumpulan informasi identitas pribadi seperti nama, nama organisasi dan posisi pekerjaan, dimana data ini akan berpotensi untuk mengungkap data pribadi. Penelitian ini akan memitigasi resiko dari pelanggaran data dengan menggunakan sistem TU Delft.*	☐	☐
5. I understand that personal information collected about me that can identify me, such as name, organisation name and job title will not be shared beyond the study team. *5. Saya mengetahui jika informasi pribadi yang dikumpulkan dan yang bisa digunakan untuk mengidentifikasi saya, seperti nama, nama organisasi dan posisi pekerjaan tidak akan dibagikan diluar tim riset*	☐	☐
6. I understand that the (identifiable) personal data I provide will be destroyed in 1 month after the completion of the research *6. Saya mengetahui data pribadi yang dikumpulkan akan di hapus dalam 1 bulan setelah penelitian selesai*	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		

	Yes *Iya*	No *Tidak*
7. I understand that after the research study the de-identified information I provide will be used for report *7. Saya mengetahui bahwa setelah penelitian selesai, informasi yang dikumpulkan akan digunakan untuk pembuatan laporan*	☐	☐
8. I agree that my responses, views or other input can be quoted anonymously in research outputs *8. Saya setuju jika jawaban atau informasi dapat di kutip secara anonimus dilaporan penelitian*	☐	☐
9. I understand that access to the output (report) of this repository is open for public *9. Saya mengetahui jika laporan akhir penelitian dapat di akses oleh umum*	☐	☐

Signatures

____________________________ ___________________________ _________

Name of participant [printed] Signature Date

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

__________________________ ____________________ _________

Researcher name [printed] Signature Date

Study contact details for further information: [*Name, phone number, email address*]