FAKULTÄT II – INFORMATIK, WIRTSCHAFTS- UND RECHTWISSENSCHAFTEN

Formation and Operation of A System of Innovation for A New Technology Field in Developing Countries through Collaborative Networks: The Case of Smart Grid in Indonesia

Dissertation

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Hiermit erkläre ich and Eides statt, dass ich die vorgelegte Dissertation mit dem Titel ,, *Formation and Operation of A System of Innovation for A New Technology Field in Developing Countries through Collaborative Networks: The Case of Smart Grid in Indonesia"* selbständig verfasst, keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt und die den benutzten Werken wörtlich oder inhaltlich entnommenen Stellenkenntlich gemacht habe.

Oldenburg, den 27.12.2022

Sri Rahayu

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Executive Summary

Actors, interaction, and infrastructure are often mentioned in technological innovation system (TIS) studies as the main components of a system of innovation. The detection of availability of those components in various case studies has been part of discussions for many years. But how the system of innovation itself could even exist and function to develop a specific type of technology, especially in less developed countries, is a further question that needs to be extensively addressed. This study explores the interaction between actors grouped in innovation networks as the main engine for building and implementing functions of a system of innovation in developing countries. In general, this study may help to provide inputs for formulating innovation policies and technological support agendas to expand the market of clean technologies in those nations.

Through utilizing a mixed research approach and focusing on smart grid technologies in Indonesia as the core of study, the findings reveal that between 2009 and 2019 there were various collaborative movements dedicated to smart grid technologies.Those movements categorized themselves into three differrent types of innovation nexuses that showed to create nurturing ecosystems for the novel innovation. Those innovation nexuses included:1) The political decision-based network that dedicated primarily to the implementation of government top-down programs with topics including the rural electrification and was facilitated by the e-nergy policy maker; 2) The business-based network related to green technologies that was led by the in-cumbent firm; 3). The knowledge-based network that was guided by the regulator of the national research and higher education.

Those three networks were found to be less centralized and had frail connections among stakeholders. This conceivably produced opportunities for a limited number of powerful stakeholders which owned a significant central position within networks to influence those networks. They had potentials in either controlling the circulation of information or supporting or even hindering stakeholders to continue their movements. Furthermore, those networks experienced a similarity in the form of a high concentration of activities for knowledge exploration related to the novel technology. It depicted that the novel technology, in general, was not yet ready to be directly commercialized without re-configuration or multiple tests done by early adopters. In addition, they also simultaneously showed a lack of interest of society towards the innovation, especially due to its costs, the need for supporting infrastructure, and limited access information about the innovation. Furthermore, lacked political support were also seen as a common challenge for those networks.

Nevertheless, each network showed its distinguished strengths and weaknesses, like different channels that can be used to introduce a novel technology. First, the network led by the energy policy maker showed its effectiveness in testing or marketing a novel technology that might be sellable or test-able in local markets in a limited range of time. The policy maker eased the process due to its existing social-political connections and influence toward its population. The disadvantage of this channel included the high dependency on the political will of the government to provide a sustainability of agendas for the network. Second, innovation network that needed resources owned by the incumbent firm was better for introducing new products that were already commercial or have high possibilities to be sellable in local markets. In this context, innovators

possibly built a relationship with the incumbent firm due to its established business infrastructure. Access to the incumbent firm's business linkages as well as legitimation in local society owned by the incumbent firm were some of the benefits gained by the innovators. Meanwhile, the incumbent firm joined into a relationship with the innovators to explore the novel technology as well as to prepare strategies to overcome the innovators. The network might experience problems when unhealthy competition between innovators and the incumbent firm took place. Third, the innovation network formed and operated within the academic realm was quite an effective platform to introduce concepts or ideas about the disruptive innovation to a large population of students or potential younger generation. Since it focused on basic research, only a top-down program from government, or big initiatives from both academics and industry that can enable the network to grow faster in order to develop sellable innovations.

Kurzfassung

Akteure, Interaktion und Infrastruktur werden in Studien zu technologischen Innovationssystemen (TIS) häufig als die Hauptelemente eines Innovationssystems genannt. Die Feststellung der Verfügbarkeit dieser Komponenten in verschiedenen Fallstudien ist seit Jahren Teil vieler Diskussionen. Aber wie das Innovationssystem selbst überhaupt existieren und funktionieren könnte, um eine bestimmte Art von Technologie zu entwickeln, insbesondere in weniger entwickelten Ländern, ist eine andere wichtige Frage, die umfassend untersucht werden muss. Diese Studie untersucht die Interaktion zwischen den in Innovationsnetzwerken zusammengeschlossenen Akteuren als den Hauptmotor für den Aufbau und die Implementierung der Funktionen eines Innovationssystems in Entwicklungsländern. Diese Studie könnte dazu beitragen, Inputs für die Formulierung von Innovationspolitiken und technologischen Unterstützungsplänen zu liefern, um den Markt für saubere Technologien in diesen Ländern zu erweitern.

Durch die Verwendung eines kombinierten Forschungsansatzes und die Konzentration auf *Smart-Grid*-Technologien in Indonesien als Kern der Studie zeigen die Ergebnisse, dass es zwischen 2009 und 2019 verschiedene kollaborative Strömungen gab, die sich den *Smart-Grid*-Technologien widmeten. Diese Strömungen gruppierten sich in drei verschiedene Arten von Innovationsnetzwerken, die ihr Potenzial zur Schaffung fördernder Ökosysteme für die neuartige Innovation zeigten. Zu diesen Innovationsnetzwerken gehörten: 1) Das politikbasierte Netzwerk, das sich in erster Linie der Umsetzung staatlicher Top-Down-Programme zum Thema der ländlichen Elektrifizierung widmete und von energiepolitischen Entscheidungsträgern unterstützt wurde; 2) das unternehmensbasierte Netzwerk im Bereich der grünen Technologien, das von den etablierten Unternehmen geleitet wurde; 3). Das wissensbasierte Netzwerk, das von der Aufsichtsbehörde für nationale Forschung und Hochschulbildung geleitet wurde.

Diese drei Netzwerke waren weniger zentralisiert und wiesen eine schwache Verbindung zwischen den Akteuren auf. Dies eröffnete einer begrenzten Anzahl mächtiger Interessengruppen, die eine zentrale Position in den Netzwerken einnahmen, die Möglichkeit, diese Netzwerke zu beeinflussen. Sie hatten das Potenzial, entweder die Informationsverbreitung zu kontrollieren, die Akteure bei der Fortsetzung ihrer Bemühungen zu unterstützen oder sogar zu behindern. Darüber hinaus wiesen diese Netzwerke eine Ähnlichkeit in Form einer hohen Konzentration von Aktivitäten zur Wissenserschließung im Zusammenhang mit der neuen Technologie auf. Es zeigte sich, dass die neue Technologie ohne Neukonfiguration oder mehrfache Tests durch Early Adopter nicht kommerziell vermarktbar war. Außerdem wiesen sie gleichzeitig mangelndes Interesse der Gesellschaft an der Innovation auf, das insbesondere auf die Kosten, die Notwendigkeit einer unterstützenden Infrastruktur und den begrenzten Zugang zu Informationen über die Innovation zurückzuführen ist. Des Weiteren wurde die fehlende politische Unterstützung als häufige Herausforderung für diese Netzwerke angesehen.

Dennoch wies jedes Netzwerk unterschiedliche Stärken und Schwächen auf, wie z. B. verschiedene Kanäle, die für die Einführung einer neuen Technologie genutzt werden können.

Erstens zeigte das vom energiepolitischen Entscheidungsträger geleitete Netzwerk seine Effektivität bei der Erprobung oder Vermarktung einer neuartigen Technologie, die auf dem lokalen Markt in einer begrenzten Zeitspanne verkauft oder getestet werden kann. Der politische Entscheidungsträger erleichterte den Prozess aufgrund seiner bestehenden gesellschaftspolitischen Verbindungen und seines Einflusses auf die Bevölkerung. Der Nachteil dieses Kanals bestand darin, dass er in hohem Maße vom politischen Willen der Regierung abhängig war, um die Nachhaltigkeit der Agenden des Netzwerks zu gewährleisten.

Zweitens war das Innovationsnetzwerk, das Ressourcen, die im Besitz des etablierten Unternehmens waren, benötigte, besser für die Einführung neuer Produkte geeignet, die bereits kommerziell waren oder gute Chancen hatten, auf den lokalen Märkten verkauft zu werden. In diesem Zusammenhang bauten die Innovatoren womöglich eine Beziehung zu dem etablierten Unternehmen auf, da dieses über eine etablierte Geschäftsinfrastruktur verfügte. Innovatoren profitierten vom Zugang zu den Geschäftsbeziehungen und zur Legitimation in der lokalen Bevölkerung, die zu dem etablierten Unternehmen gehörten. Gleichzeitig ging das etablierte Unternehmen eine Beziehung mit den Innovatoren ein, um die neue Technologie zu erforschen und Strategien zur Überwindung der Innovatoren vorzubereiten. Das Netzwerk könnte in Schwierigkeiten geraten, wenn es zu einem ungesunden Wettbewerb zwischen Innovatoren und dem etablierten Unternehmen kommt.

Drittens war das im akademischen Bereich gebildete und betriebene Innovationsnetzwerk eine recht effektive Plattform, um Konzepte oder Ideen über disruptive Technologien einer großen Gruppe von Studenten oder einer potenziellen jungen Generation vorzustellen. Da es sich auf die Grundlagenforschung konzentrierte, kann nur ein staatliches Top-Down-Programm oder eine große Initiative von Wissenschaft und Industrie das Netzwerk in die Lage versetzen, schneller zu wachsen und die Entwicklung oder Umgestaltung von vermarktbaren Innovationen zu fördern.

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List of Abbreviations

ACE	:	Asean Centre for Energy
ADB	:	Asian Development Bank
AMI	:	Smart Meter Infrastructure
APEC	:	Asia Pacific Economic Cooperation
ASEAN	:	Association South East Asian Nations
BPPT	:	*Badan Pengkajian dan Penerapan Teknologi*
Co-opetition	:	Cooperation and competition
EU	:	European Union
FIT	:	feed in tariff
GW	:	Gigawatt
GIZ	:	*Deutsche Gesellschaft für Internationale Zusammenarbeit*
HIVOS	:	*Humanistisch Instituut voor Ontwikkelingssamenwerking*
IBEKA	:	*Institute Bisnis Ekonomi dan Kerakyatan*
IRENA	:	International Renewable Energy Agency
ICT	:	Information Communications Technology
IEA	:	International Energy Agency
IMEMR	:	Indonesian Ministry of Energy and Mineral Resources
IMHA	:	Indonesian Ministry of Home Affairs
IMNDP	:	Indonesian Ministry of National Development Planning
IMRHE	:	Indonesian Ministry of Research and Higher Education
Int’		International
Int’ NGO	:	International Non Governmental Organization
Int’ R&D centers	:	International research and development centres

Interviewee Nr.		Intervieweee number
kW	:	kilowatt
kWh	:	Kilowatt hour
kWp	:	kilowatt peak
local R&D centers	:	Local research and development centres
MSSRI	:	Ministry of State Secretariat of Republic Indonesia
mW	:	megawatt
MWp	:	Megawattpeak
NEDO	:	The New Energy and Industrial Technology Development Organization- Japan
NGO	:	Non Governmental Organization
PDR	:	People Democratic Republic
PJCI	:	*Prakarsa Jaringan Cerdas Indonesia*
PLN	:	*Perusahaan Listrik Negara*
PV	:	Photovoltaic
R&D activities	:	Research and development activities
R&D centers		Research and development centres
RUKN	:	*Rencana Umum Ketenagalistrikan Nasional*
RUPTL	:	*Rencana Usaha Penyediaan Tenaga Listrik*
SCADA	:	Supervisory Control and Data Acquisition
TIS	:	technological innovation system
UN	:	United Nations
USAID	:	The United States Agency for International Development
VPP	:	Virtual Power Plant

1 Introduction

This chapter explains the motivation of the research, a statement of the problem, its aims, and significance of the reseach. In addition, objectives, research questions and an outline of the thesis are also presented.

1.1 Motivation

Over the last decade, developing countries have experienced problems concerning their power sector. A significant growth in energy demand due to rapid economic changes has led to them becoming more dependent on fossil fuels. This condition has aggravating effects on the environment, including air pollution and climate change (Gardner 2007; Elias and Victor 2005; Ahuja et al. 2009). In addition, until now, these countries still have a relatively high proportion of the population living without access to a modern and sustainable electricity supply (National Renewable Energy Laboratory (NREL) 2020); Waissbein et al. 2018; Cox et al. 2018). To solve these problems, various approaches to gain more energy efficiency and to adopt alternative energy technologies have been proposed and introduced. Both industrialized and developing countries acknowledge the benefits of renewable energy, both due to its availability and the fact that it produces fewer greenhouse gas emissions (Elias and Victor 2005; Dantas et al. 2018; Darmani et al. 2014; Hussain et al. 2017).

Southeast Asian countries are among those developing countries that have recently increased their energy demand, especially for oil, gas, and coal, to support their industrialization and development activities. According to International Energy Agency (IEA) (2013a) and Huber et al. (2015), the energy demand of Southeast Asian countries will reach 1,004 Mtoe (Million tons of oil equivalents) in 2035, or an increase of 85% from the 2011 energy demand. Moreover, Indonesia has the greatest energy demand in Southeast Asia, mainly due to demographic dynamics and economic growth. However, in 2011, there were approximately 134 million people from rural areas in Southeast Asia that live without reliable power access, and most of these people reside in Indonesia (Gielen et al. 2017). Between 1990 and 2015, the diffusion of renewable energy resources in the region, especially for power generation, was not greatly developed. Hydropower was still one of the most-used renewable energy technologies for generating electricity. At the same time, Hiebert et al. (2012) and Nagpal & Hawila (2018) report that the contribution of hydropower to the power sector in Southeast Asia was around 20% from total power output in 1990 but it then significantly decreased in 2013 to 14%, partly due to the degradation of environmental conditions in some areas and the introduction of new technologies for power generation. On the other hand, the contribution of other renewable energy technologies, such as geothermal, wind, solar, and bioenergy grew slowly from less than 1% in 1990 to 10% in 2018 (International Energy Agency (IEA) 2019).

Concomitantly, smart grids have been introduced in developing countries as an innovative approach to modernize the management of centralized grids, decentralized grids and off-grid systems using information and communication technologies (ICT) (Alotaibi et al. 2020; Bigerna et al. 2015). Through smart grids, a 'smarter energy system' or the 'internet of energy' can be created to sustain more reliable and efficient electricity production, distribution and consumption in terms of technical, economic, social and environmental aspects (Bari et al. 2014; Demertzis et al. 2021). In order to do that, smart grids consist of hardware as well as systems and software that focus on different technology areas, such as for ICT integration, renewable energy and hybrid power plant integration, wide area monitoring and control, transmission enhancement, consumer-side system, electric vehicle charging, advanced metering infrastructure, and distribution grid management (Morteza and Mohsen 2013). As an example, smart grid technology is able to provide power generators with useful services including real-time information about demand, market price and weather forecast (Kempener et al. 2015). In addition, smart grids consist of some techno-logies (e.g. smart metering) that provide opportunities for consumers to have real-time information about price and energy supply so that they are well informed about the power that they want to consume (Hossain 2012). Moreover, the microgrid and the smart city models provide novel approaches to integrate consumers and producers of energy in a smart energy system (Komor et al. 2013).

Smart grid technologies offer a significant potential to establish a sustainable energy system, especially by maximizing the role of renewables in the power system. According to Speer et al. (2018), Schaube et al. (2018), Reber et al. (2016), Ecuru (2013), and Liu & Zhong (2018), smart grids can overcome challenges that occur in renewable energy-based electricity production. First, smart grids handle the issue of variability. A high dependency on weather conditions (especially for wind and solar) makes renewable energy resources less reliable in covering demand. By using smart weather forecasting, or a virtual power plant or microgrid, various renewable energy generations from different types of technologies can be combined to cover demand in a more flexible, efficient and reliable way. Second, smart grids potentially integrate various small and medium sizes of distributed renewable energy generators to be optimally operated and visible in the market. In this context, smart grids also promote a decentralized power system that can potentially be performed by smartly combining various types of renewable energy power generations and storage technologies.

Furthermore, Ahuja et al. (2009), Feng (2016), Zhang et al. (2012), and Numata et al. (2018) assert that smart grid development in developing countries could provide more energy efficiency and enhance rural electrification based on renewable energy sources. In this context, some literature mentions that microgrids are among the smart grid technologies that have a great potential to be deployed in developing countries (Alotaibi et al. 2020; Brasington 2018; Kempener et al. 2015). A microgrid consists of power generators (including power plants from renewable resources), storage technologies, and loads that promote a more decentralized electrification system; and has a centralized control hardware and software that is able to manage and to optimize the operation of various renewable energy resources to cover loads in a certain area (Tjäder and Ackeby 2014). Micro/minigrids can be designed on-grid and off-grid. According to the size, a microgrid can be divided into three definitions: picogrid (2 kW-10 kW), microgrid (10 kW-1MW), and minigrid (1MW-2 MW) (Tridianto et al. 2018). A microgrid can be installed in buildings, campuses, industrial areas, and villages/districts (Numata et al. 2018).

The use of smart grids is one of the many alternatives that has already started to be introduced in Southeast Asia to further exploit renewable energy potentials. Based on research from (Huber et al. 2015; Osman 2014; Asean Centre for Energy (ACE) et al. 2018), 7 out of 10 of the ASEAN member countries has already issued their smart grid development and implementation plan and began to undergo demonstration projects. Microgrids, smart meters and electric vehicles are types of smart grid technologies that are mainly introduced in the region. Other than that, there is a variation in terms of how those countries try to embrace smart grids. In the Philippines, for example, the government plans to enrich feasibility studies and policy research projects about smart grids but with a less concrete target in deploying on-site pilot projects (Association of South East Asian Nations (ASEAN) 2015). In Singapore on the other hand, smart meters in public housing is the popular goal beside the introduction of a decentralized system using microgrids in its remote islands (Vithayasrichareon 2016; Liu and Zhong 2018). Meanwhile, projects concerning smart grid standardization and microgrid implementation on remote islands, as well as in industrial districts, enhanced by energy policy makers and electricity monopolists have started to take place in Indonesia, Vietnam, Laos, and Malaysia. Studies done by Asean Centre for Energy (ACE) et al. (2018), German Federal Ministry for Economicy Affairs and Energy (BMWi) (2016), The United States Agency for International Development (USAID) (2019b) and Arifin (2019c) also show that enthusiasm from individuals in installing smart meters for Rooftop PV prosumers has increased significantly in Vietnam and Indonesia. They report that until the beginning of 2018, those two countries together had a total of between 10 and 13 MW of installed capacity of residential rooftop PV (Photovoltaic) which allowed individuals to conduct export and import of electricity to and from the national grid.

Subsequently, as a subject that runs side by side in potentially boosting the utilization of alternative energy resources, diffusion and development of smart grids in developing countries, especially in Southeast Asia, have been challenging tasks. The problem is not only in terms of transferring the ready and available smart grid technologies to their potential markets in emerging nations, but also the urgency to understand the conditions of local potential users of those technologies (Davidson et al. 2008). It is essential to find out what they want and the potential difficulties while trying to embrace those new technologies (Ezell and Atkinson 2010). According to Groh (2015), Esmailzadeh et al. (2020), and Alsanad & Abdel-Razek (2013), diffusion of green technologies in developing countries would likely face some challenges, including a lack of information and access to products, difficulties in accessing finance, infrastructure incompatibility, the high cost of technology, and a lack of enabling business environment. Nevertheless, those obstacles are dynamic (Bittencourt et al. 2021; Bittencourt et al. 2020b; Quitzow 2015). In other words, actors, infrastructure, and technology itself are not static but concevably changing overtime. In the process, these elements might interract with each other in order to either enhance or hinder the diffusion and development of the novel technology (Suurs and Hekkert 2009; Suurs 2009; Cap et al. 2019). A good synergy between those elements together with the implementation of an effective strategy could create an ideal environment (Nambisan and Sawhney 2011; Ahuja 2000).

Moreover, a technological innovation system (TIS) approach furthers that the development of a specific technology in a certain place has its own stages and paces. One of the ideas that comes from this approach is the dynamic features of a technology as well as the dynamic actions of actors involved in developing and diffusing the technology in their networks that are able to describe to what extent has the technology been embraced by a society. Subsequently, the availability of demonstration plants, scientific publications, R&D projects, funding, fiscal policy, long-term visions, and lobbyings are among the intermediate output generated by them in order to create a new technological regime. Recent studies undertaken by (IIzuka and Gebreeyesus 2017; Mohammadi et al. 2013; Tigabu et al. 2015a; Byrne et al. 2012; Edsand 2016; Gosens and Lu 2013; Kebede and Mitsufuji 2017; Siegel and Strong 2011; Yam et al. 2011) explicitly examine the applicability of a technology innovation system framework to enhance the adoption and diffusion of renewable energy technologies, especially in developing countries. The studies found that a stronger technological innovation system increases more positive actions of involved diverse stakeholders located in emerging countries in generating outputs, such as publications, fiscal policies, funding schemes, network platforms, knowledge sharing programs and on-site pilot projects. The better the result, the better the functions of the system could be.

1.2 Statement of the problem or gaps

<u>Critics towards technological innovation (TIS) approach due to its lack of bottom-up approach</u>

A Technological innovation system (TIS) is defined as a set of networks of actors and institutions that jointly interact in a specific technology field and contribute to the generation, diffusion and utilization of variants of a new technology or product (Bergek et al. 2015; Bergek et al. 2008b; Markard and Truffer 2008). The approach emphasizes the emergence of its components, e.g. actors, technology, and institutions, in creating a value chain that reduces barriers and increases competitive relationships as well as generating a collective strategy at a broader level (Wieczorek and Hekkert 2012). The approach, however, is not without critics. Musiolik & Markard (2011) and Wesche et al. (2019) elaborate that the approach successfully introduces a categorization of actors in terms of their activities and competencies, for example policy makers, firms, research institutes etc. Common strategic policy is also one of the prominent outputs derived from an analysis based on the approach. However, it provides a lack of comprehensive explanations as to why several actors, even though they have the same competencies, tend to contribute to the system differently. Musiolik (2012) asserts that most of the current discussions related to technological innovation systems emphasize too much on the structure of the component and its macro-output indicators by assuming that the system is already given. He also adds that the discussions about how, why and when the system is created and functions are still limited in their scope.

Subsequently, Mohammadi et al. (2013) and Bittencourt et al. (2020b) argue that there is an urgency to have more discussions about the process of formation of as well as the management of actions undertaken by stakeholders within a technological innovation system. They elaborate that in order to do so, the research should focus on a limited number of specific network platforms, where the actors could interact with each other in order to build systemic innovation processes. From this point, the different behaviours of each actor in shaping the existence of the technology should also be the focus point and be optimally examined. Each network platform might consist of a certain actor that has the most significant resources and is able to build a systemic coordination between actors to ease the development or utilization of the technology (Busquets 2010; Hurmelinna-Laukkanen et al. 2022).

<u>The need of an analysis of collaborative networks that possibly enhances the formation and creation of TISs for smart grid technologies in Indonesia</u>

Investigations about the potential formation of a technological innovation system in Indonesia that have been initiated through the identification of a group of collaborative movements united in a specific innovation network are very difficult to be found (Lakitan 2013; Park et al. 2021; Rofaida et al. 2019; Lakitan 2019; Zu Koecker and Saxena 2012). The number of pieces of literature about systematic innovation in Indonesia that covers smart grid technologies is also still limited. Most of the studies related to smart grids in Indonesia focus either on macro conditions or on specific projects.

Subsequently, smart grid activities in Indonesia are found in centralized activities or at a macro level, which consist of projects for mapping the potential of smart grids at a national level and deriving policy recommendations (Römer et al. 2017; Allotrope Indonesia 2017; Aprilia 2017; Arie 2018; Arinalso et al. 2018; Asean Centre for Energy (ACE) et al. 2018; Asian Development Bank (ADB) 2016; Gielen et al. 2017; International Renewable Energy Agency (IRENA) 2017). At the same time, decentralized activities or movements at a micro level in form ofprojects about the description of the installation and functionality of a specific technology in a certain location are also examined by a limited number of studies (Fauzi et al. 2016; Giriantari and Irawati 2016; Hamdi 2019; Haryadi et al. 2021; Ma et al. 2018 - 2018; Manik et al. 2014). In general, those studies depict implicitly that actors involved in smart grid activities in Indonesia come from different organizational backgrounds, including policy makers, end-users, universities, research facilities, and energy consultants. In addition, those activities are still scattered without a common strategic coordination (Arifin 2021c; Lauranti and Djamhari 2017). Furthermore, the urgency to find a strategic, specific and systemic framework in order to connect movements at a macro and at a micro level is among the recommendations from those studies (Hamdi 2019; Lontoh et al. 2016; Römer et al. 2017).

Meanwhile, in 2012, three governmental-related bodies of Indonesia, the policy maker of energy, the state-owned utility/monopolist/incumbent firm, and the research and higher education policy maker, started to express their interest in smart grids (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2012a; Indonesian Ministry of Research and Higher Education (IMRHE) 2015; Perusahaan Listrik Negara (PLN) 2018). Sponsoring on-site demonstration projects and R&D activities, setting up goals for smart grid adoption as well as deploying fiscal & non-fiscal instruments are among the activites carried out by those organizations. Those actions have triggered a broad range of actors to respond and participate.

According to arguments explained by Pushpananthan (2022) and Dhanaraj & Parkhe (2006), initiatives from those three organizations may concomitantly and informally induce the creation of hubs or nexuses that make many actors interested in joining or participating. In this context, each of those three organizations possibly acts as a central or a leader of the nexus. Within the nexus, interactions of different actors is possibly increased. At the same time, because of their notable standing position in terms of politics, social as well as economy, those three organizations may lead and influence their network by influencing the behaviour or decision making of other actors towards the new innovation (Pikkarainen et al. 2017). Any action of those organizations, either positive or negative, conceivably shapes the direction of the systemic innovation processes carried out by their nexuses (Geels 2014). In addition, each network which is dedicated to a certain novel technology conceivably performs distinctively due to the specific characteristics of its leader as well as the behaviour of its members. When the community within the nexus is dynamic, the leader may be more innovative; however, when the community within the nexus is reluctant to embrace the new technology, the leader may be also reluctant (Rogers 1983). Nevertheless, when two communities are identical in terms of the social, economic and political situation but each community has a presence of different leader characteristics, then diffusion of innovation in each community may vary (Rogers and Cartano 1962). A more adaptive and innovative leader tends to encourage its community to utilize and may re-invent the technology, and vice versa (Rogers 1983; Calia et al. 2007).

1.3 The aim and significance of the study

Aim

A technological innovation approach pays attention to the role of each interaction, e.g., network, among actors. Networks connect the varied knowledge of a broad range of actors, e.g. producers, suppliers and users, from diverse locations and organizational backgrounds, facilitate speedy information excange and subsequently contribute to decision-making processes. Furthermore, actions to be undertaken by particular innovation processess are usually done by multiple small groups that belong to networks (Pyka and Scharnhorst 2009).

Based on this, the research is aimed at examining multiple collaboration arrangements grouped into different networks for smart grid diffusion in Indonesia. This study brings together and explores the interaction between actors through collaborative activities grouped within innovation networks as the main engines in building, as well as in implementing, the functions of a system of innovation in developing countries. Smart grids have been chosen as the main subject in this study to be introduced and developed in the system of innovation.

Significance of the study

- Actors, interactions and infrastructure are often mentioned in technological innovation system studies as the main components of a system of innovation. The availability of those components in various case studies has been part of many discussions for several years. But how the system of innovation could exist and function in order to introduce, as well as develop, a specific type of technology, especially in less developed countries, is a further question that needed to be addressed. In this research, different innovation networks dedicated to smart grid technologies in Indonesia are assessed in order to find out to what extent they develop into system of innovations.
- The study also contributes to literature in how the characteristics of collective resource management and the interventions of leading actors either potentially enable or hinder the innovation networks. Through case studies, the research provides the advantages and disadvantages of each network in various scenarios in order to formulate comprehensive strategies in developing each specific network into a potential pioneer of system of innovation.

1.4 Objectives

The research aims to analyse the evolution of collaborative movements grouped in innovation networks in building and performing functions of a system of innovation that empower smart grid technologies for enhancing a more sustainable power system in Indonesia.

1.5 Research questions

This study was guided by five research questions, which are as follows:

1. Have there been any collaborative projects related to smart grids in Indonesia which can categorize themselves into different networks, e.g. political decision-based network led by the energy policy maker, business-based network led by the state owned-utility/monopolist/incumbent firm, and knowledge-oriented network led by the research & higher education policy maker? Furthermore, what has the general feature of those movements been so far?
2. What are the general characteristics of common resource management practiced by the stakeholders while conducting collaboration projects within innovation networks for smart grids in Indonesia?
3. To what extent have the potential and actual intervention of leading actors in smart grid activities in Indonesia, e.g., the energy policy maker, the state-owned utility/monopolist/incumbent firm and the research & higher education policy maker, developed or even hindered their own networks?
4. To what extent have collaboration projects related to smart grid within those three networks operated different functions of a system of innovation dedicated to smart grids in Indonesia?
5. What are the specific advantages and disadvantages of each innovation network and what are strategic mechanisms for optimizing its performance as an embryo of the innovation systems for smart grids in Indonesia?

1.6 Outline of the thesis

This dissertation is organized as follows:

- The first chapter of this dissertation presents the background, followed by the importance, motivation and scope of the analysis. It further explains the problem of the study that is then used as a basis of objectives to solve the problems. The final part of this introduction is the the outline of the thesis.

- The second chapter describes theories about the technological innovation system (TIS) approach and innovation networks. Their definitions, elements, functions and distinctions towards other approaches are explained.
- The third chapter provides explanations regarding the process of the research in building its conceptual framework. It begins with criticism towards the TIS approach due to its lack of analysis in explaining the process of its own formation by using more bottom-up perspectives. Subsequently, the narration about the potential of innovation networks as pioneers of TIS because of their ability in performing and building functionality of TIS is presented. Furthermore, the chapter also delivers a literature review about the strategy of creating system of innovations in the context of developing countries through collaborative movements with the case of smart grid movements in Indonesia and its neighbouring countries. Finally, the chapter illustrates the conceptual framework that is used as a foundation in collecting the data.
- The fourth chapter presents the research methodology of the thesis. The chapter at first gives descriptions about smart grid activities in Indonesia and introduces three case studies: a network for smart grids developed by the energy policy maker, a network for smart grids supervised by the incumbent firm/electricity monopolist, and a network for smart grids enhanced by the research and higher education regulator. It then states the scope and boundaries of the study. Population and sampling methods, data collection methods, the character of respondents as well as the methods for data processing and analysis are provided in the chapter.
- In the fifth chapter, the results of analysis for case 1 are presented. It covers the dynamics of the network that were facilitated by the energy policy maker of Indonesia in implementing the functions of the technological innovation system for smart grids. The performance of various actors through collaborative platforms as well as the influence of the policy maker within the network are assessed in the chapter.
- The sixth chapter provides the results of the investigation relating to case 2. It shows how the state-owned electricity monopolist in Indonesia created and controlled its smart grid innovation network. The enthusiasm and current performance of various actors within the network are also presented in the chapter.
- In the seventh chapter, the results of the examination of case 3 are presented. It analyses the performance of smart grid innovation network supported by the education policy maker. The potential, as well as actual intervention of the education policy maker in influencing collaborative innovation processes for smart grids within its network are also explored. The significant role of universities as main players in the network are also illustrated in the chapter.
- The eighth chapter presents the comparison analysis between three case studies, followed by a scenario analysis. The degree of competitiveness of each case study as well as the strategies to optimize the general performance of smart grid movements in Indonesia are also presented in the chapter.
- The ninth chapter provides the conclusion and proposed future research recommendations for the topic of the study.

2 Understanding the general concept of a technological innovation system (TIS) and innovation network

This chapter provides an explanation of the general theories of a technological innovation system (TIS) and innovation network. Basic terminology, types and aims of both concepts are presented.

2.1 A Technological innovation system (TIS)

According to Schumpeter (1934), innovation is always correlated to economic development and is the key to production activity embedded in our economic and social systems. He also adds that innovation includes a new product, a new process, and a new way of organizing various elements in the productive sector (industry/economy). While the basic concept of innovation from Schumpeter is widely accepted and acknowledged, several scholars, including Freeman (1989), Kline & Rosenberg (1986), and Rogers (1983), confront the model of Schumpeter and his followers which illustrates innovation activities as a linear process. They argue that a linear innovation process that includes basic research, applied research, development, and production/diffusion is somehow debatable.

Specifically, Kline & Rosenberg (1986) assert that innovation processes may need a long mechanism in which different interlinked sub-processes take place. Accordingly, Pavitt (1987) also explains that innovation is gained through so-called innovation processes, where they refer to seeking chances for creating products or service improvements based on either existing knowledge or the tendency of new market creation or a combination of both. Those processes, therefore, are not always started with basic research. He also describes that these processes depend on efforts to accumulate knowledge through learning within the process of production, marketing and utilization. In addition, Freeman (1989), argues that it is difficult to analyze innovation processes as a linear mechanism because it only offers an understanding that knowledge and technologies are generated with a lack of processes that undergo interactions with social needs. He suggests that innovation processes critically depend on interactions with external environments, such as consumers, suppliers, competitors and policy makers. Rogers (1983), based on his research about innovation diffusion, also ilustrates that innovation is a something new for end-users, so it needs a process of production and adoption that requires communication activities that involve a broad range of actors, especially between innovators, potential end-users, and institutions, e.g., social-economical rules over a certain period of time, in order to share information and gain reciprocal perception. He adds that the result of the process is either rejection towards the innovation by end-users or the creation of a limited scale of adoption of the innovation, or massive adoption that leads to significant changes in the behaviour of a significant number of consumers or economic-social conditions.

Meanwhile, for the last three decades there has been an increased number of innovation studies that adopt the term of system of innovation (Smits et al. 2010; Suurs and Roelofs 2014; Haase et al. 2013; IIzuka 2013). Those investigations are not focused on innovation activities based on macro-economic indicators, but shift their attention to processes that connect various elements of innovation movements together, including individual companies, markets, institutions, networks and consumers. Rothwell (1994), for example, states that it is time to see innovation as a combination of ''supply push'' and ''demand-pull'' by analysing it as a process of reciprocal communication between business-technological potential and what markets want. He adds that those interactions are then seen in several ''back and forth'' and dynamic mechanisms for learning and resource accumulation that involves networking conditions between heterogonous organizations and individuals in order to create a new technological regime.

Related to that, Andersen & Andersen (2014), Anadon et al. (2016), and Velu et al. (2010) also argue that an innovation system is about processes that bring together the performance of firms in providing solutions or new products and their complex linkages with their environment in terms of social and economic relationships in order to enhance learning or knowledge accumulation processes. Innovation processes in this case are mostly in term of heterogenous, scattered and autonomous actions that might be systemically synchronized by involving various elements to interact with each other. In addition to that, Carlsson et al. (2002) assert that systems of innovation can be observed in different kinds of unit measurements, including in a specific geographical area, at a national level, in a specific industrial sector or for a specific type of technology. He elaborates that each unit of measurement usually describes its specific scope, aims, rules of the game, structures of elements, and dynamic interconnectedness between elements.

2.1.1 Definition and elements of TIS

One of the earliest introductions to the technological innovation system (TIS) framework is explained by Carlsson & Stankiewicz (1991) and Metcafe (1995). They assert that a system of innovation for a particular technology refers to a nexus of different actors that interact with each other to develop, re-create, improve, commercialize, and use the novel technology under the influence of their surrounding environment, including social norms, physical infrastructure, and economic policies. They add that the interesting feature of TIS is its ability to illustrate a dynamic circulation of knowledge between actors as it wants to achieve its final outcome, including the generation of new business players, that are able to produce a novel technology in the level of mass production and transformation of niche markets of a novel technology into a new form of industry. In addition, based on his research about adoption processes of a particular new type of information and communication technology, Fleck (1994) states that the adoption of technology that requires a significant innovation reconfiguration in order to be suitable to meet local demands might end up in failure if there is insufficient interaction between innovators and users. He illustrates the definition of TIS by mentioning that in order to be together to continuously re-develop innovation, asymmetric information between them should be decreased, and the important thing is that the systemic interaction should able to answer how difficult it is for consumers to apply the technology, how difficult it is to arrange the different composition of components to meet the heterogenous demands, and how much quantity of demand of the needed technology that should be covered by considering the actual production capacity of innovators. Furthermore, Geels (2002) elaborates that TIS takes place due to uncertainty in times of development and adoption of specific new technologies, in which it might take time for them to build their supportive environment, e.g. political recognition, access to investment and interest from society.

Moreover, Carlsson et al. (2002) explain more about the basic elements of TIS that include a set of interlinkages between actors, technologies, institutions, e.g. norms, cultures, and regulations, and infrastructures that together create a certain climate in order to develop a new technology. They argue that interlinkages between actors in a TIS context can be global, national, regional and sectoral. Correspondingly, Wesche et al. (2019) assert that a TIS is also ''socio-technical systems'' that either encourage or discourage development and commercialization of specific types of technology. They add that focus of any analysis based on the TIS framework is to illustrate the structure of actors, their interactions as well as availability of institutions and infrastructures that influence them. Institutions can be differentiated into soft and hard institutions. Soft institutions include habits and routines, whereas hard institutions can be viewed as legal or codified conducts, such as legislation and standards (Bergek et al. 2008b; Bento and Wilson 2014). In addition, infrastructures can be distinguished into three categories, including knowledge/expertise/information, monetary situation, and concrete infrastructures that cover the physical appearance of technology, machines, and tools (Andersen and Andersen 2014; Hekkert et al. 2011).

2.1.2 Functions of TIS

A TIS works only if the system can enhance any activity to develop, diffuse, and use certain technologies, both in a direct and in an indirect way (Bergek et al. 2008a). Bergek et al. (2005), Bergek et al. (2008a), Bergek et al. (2010), Hekkert et al. (2007), Kao et al. (2019), and Suurs & Hekkert (2009) describe some indicators that are called system functions in order to assess to what extent a TIS evolves in enhancing innovation processes, including knowledge development and dissemination (the number of R&D projects and investments, patents, learning curves, seminars, workshops), entrepreneurial experimentation (the number of new entrants, experiments, launched products, variety of experiments), materialization or resource mobilization (the number of investments, loan, grants), and the influence of the direction of research (technology foresight, national R&D targets, long term visions/program). Carlsson & Stankiewicz (1991), Bergek et al. (2008a), Anadon et al. (2016), and Binz et al. (2014) add that principally, the TIS exists and works, if it is able to provide supports for actors in the system (especially for the private sector) through fiscal and non-fiscal incentives at the same time as to improve the awareness or interest of society or focal politicians in the new technology. Subsequently, Table 2-1 describes the detail of TIS functions, as follows:

Table 2-1 Functions of a TIS

Functions	**Descriptions**	**Indicators of achievements**
Demonstration plants and entrepreneurial activities	Setting up or sponsoring demonstration plants or technology incubation programs with possibi-lities of finding ideas to re-configure projects to be suitable in local contexts, and possibilities to create linkages with local or foreign expertise to enhance the implementations	Number of experimental projects, start-up companies
Research & Development	Conducting research and development projects either individually or through collaborations.	Number of publications, reports, patents, prototypes, international/local collaboration projects
Knowledge diffusion	Being involved in knowledge exchange programs, for example through trainings, internships, workshops and conferences	Established network for sharing information, scholarships programs, number of organized scientific events
Guidance of the search	• Providing pictures about needs and supplies of a certain technology in the future, its alternative, and its comparison to traditional technology or the current technological regime • Identifying suitability of novel technology introduced by foreign countries with domestic situation • Issuing visions and programs in order to govern the direction of development of a certain type of technology	Number reports related to techno-logy forecasting, technology consultations, programs to introduce novel technology
Market formation	Encouraging expansion of market of the novel technology, for example through fiscal incentives, actions of government as early adopters, and deployment of protection measure for the novel technology	Availability of fiscal policy, for example in form of feed in tariff, special tax reduction for production of the novel technology

Resource mobilization	Opening linkages between entrepreneurs and financial entities/ national and international donors or conducting investment on the novel technology	Number of investments related to the novel technology, local/international grants and loan
Creation of legitimacy for novel technology	• Rising awareness of groups in society to promote the new technology • Enhancing contact or political debate with policy makers to communicate ideal environmental or industrial policy that could enhance development of the new promising technology • Promoting benefit of the new technology through various medium or platforms	Availability of contacts between innovators and policy makers, number of petitions, programs or contents to advertise novel technology in various communication platforms

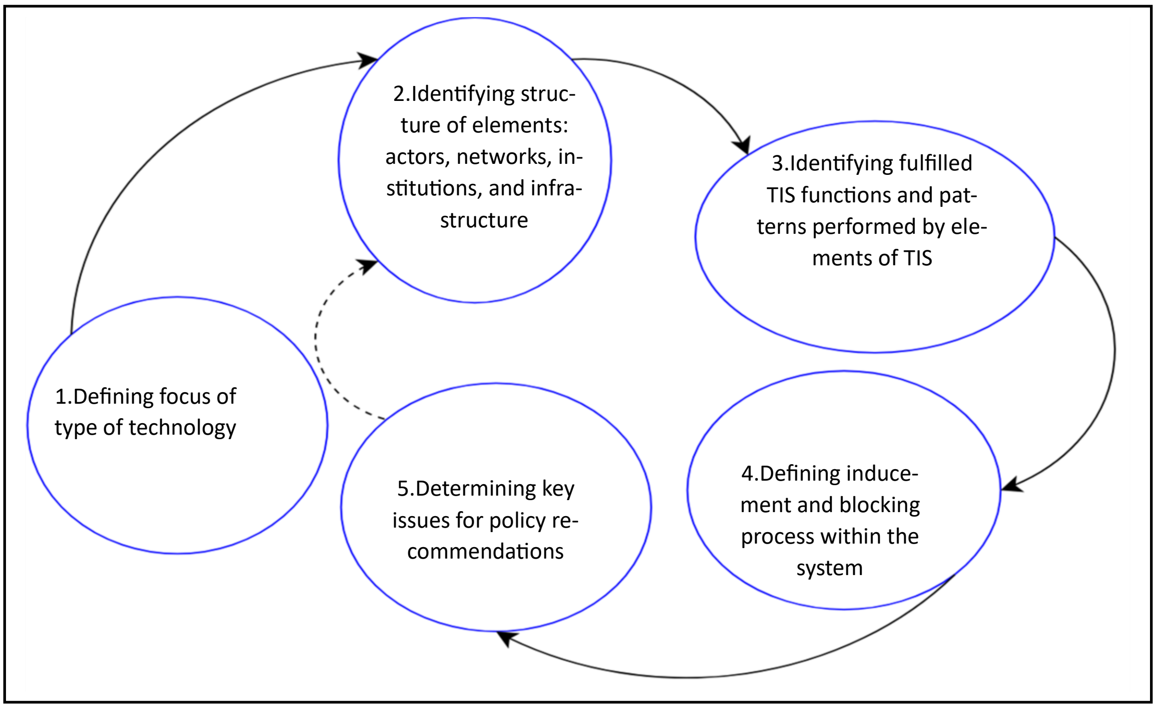
Source: (Kao et al. 2019; Tigabu et al. 2015b; Bergek et al. 2008a; Anadon et al. 2016; Brenneche 2013)

2.1.3 Advantages of TIS Framework

According to Brenneche (2013), Hekkert et al. (2007), and Markard et al. (2009), the main advantage of the TIS framework is that it is capable of offering a list of the so-called system functions as a tool to describe the achievement of the system in developing and commercializing a specific novel technology. In addition, Suurs (2009), Suurs et al. (2010), and Walz et al. (2016) argue that through the identification of system functions, the evolution of a TIS can be seen not only through its potential cumulative points of achievement in fulfilling those functions, but also through its ability to create linkages between those functions that can create either a ''vicious cycle'' or ''virtuous cycle'' for the novel technology. Furthermore, Markard & Worch (2009) argue that the TIS framework provides opportunities for scholars to study a simultaneous analysis of several types of potential technologies in order to distinguish their development process and competition between them so that a broader policy setting for a particular type of industry or business sector can be generated. It is also possible to combine the TIS framework with other approaches, especially from domains of technological transition, for example with Multi Level Perspectives (MLP) or niche strategic management (NSM), in order to better illustrate the correlation between changes in the market of a specific novel technology and the evolution of a particular industrial sector (Bergek et al. 2015; Markard and Truffer 2008).

In addition, according to Kemp & Pearson (2007), Coenen & Díaz López (2010), Markard et al. (2009), and Wieczorek & Hekkert (2012), the TIS framework has been widely used as one of several promising approaches in investigating emerging technologies due to its ability to provide a basic analysis for policy recommendations by capturing key elements to build the system as well as detecting strengths and weaknesses of the system based on its structure and fulfilment of its functions. The TIS framework also provides dynamic results in each different period of time; meaning it can show different challenges and opportunities for actors that directly work with the technology and for actors that play indirectly to the related sector (Geels 2002).

For more detail, Figure 2-1 illustrates the TIS framework that is used to generate policy recommendations. It is started by determining the focus of each type of technology that is needed to be analysed, and then is followed by identifying the structure of elements which consist of actors, their interlinkages, institutions and infrastructures. After that, the analysis is continued through assessing the functionality of the TIS and its patterns by collecting different related indicators. The next step is finding inducement and blocking mechanism processes within the system before determining the key issues for policy recommendations.



Source: Adapted from (Hekkert et al. 2007; Bergek et al. 2015)

Figure 2-1 TIS Framework

2.1.4 Formation of aTIS

There are still a limited number of TIS studies that explicitly handle the topic of TIS formation and its evolvement mechanism (Musiolik et al. 2012; Miller and Mobarak 2013). Nevertheless, Jacobsson & Johnson (2000), Suurs et al. (2010), and Winskel et al. (2014) assert that to what extent the structure of the TIS can grow is mainly influenced by the ability of the novel technology to follow the needs of users. They suggest that the formative period is the most critical because it faces periods of uncertainty due to weak or absence of a system's structure. Meanwhile, Kemp & Pearson (2007), Bento & Wilson (2014), and Wilson & Coningsby (2016) argue that TIS has three basic stages to develop, including the formative phase, the scaling up phase, and the growth phase. In addition, Markard (2020) suggests that there is also a declining phase as the growth phase comes to an end.

- The formative phase consists of activities to enhance connectivity between actors, for example in order to derive common agreement for initiating experimentation and the production of a novel technology in a limited quantity so that it is possible to test it and define its standards of compatibility with the local market (Bento and Wilson 2014). In addition, the formative phase also aims to increase information sharing within the research and development domain, and between innovators and a limited number of potential users (Wilson and Coningsby 2016; Kemp and Pearson 2007).
- On the other hand, the scaling-up phase consists of the activities of actors in advancing the potential of the novel technology through the intensification of linkages with a larger number and more diversified characteristics of end-users, a desire to formalize co-operation and competition between actors, and a high chance to generate a ''dominant design'' (Wilson and Coningsby 2016; Markard 2020). In this level, a continuous process for developing a product based on ''learning from failures'' takes place (Bento and Wilson 2014; Kemp and Pearson 2007).
- The growth phase, in addition, is a time for the novel technology to be able to be produced in large quantities in order to reach its economy of scale (Bento and Wilson 2014). The system is now transformed into a new industry due to its social-economic legitimacy as well as its capacity to be adaptive in overcoming a dynamic business environment (Bento and Wilson 2014; Kemp and Pearson 2007).
- Furthermore, the TIS may experience a decline phase when there is a decreasing interest from users to continue to utilize the products or when other new technologies come to replace the current technological regime (Markard 2020).

2.2 Innovation Network

2.2.1 Definition, components, and aims of innovation networks

The rapid development of information and communication technologies, globalization, and the dynamics of economic - political regulation along with changeable markets are among the potential factors that have shifted perspectives towards innovation processes into a different level for several decades (Hemphälä and Magnusson 2012). Revolution of innovation processes change from linear and autonomous mechanisms into activities that require openness, interactions and co-operation between stakeholders, and knowledge collecting and sharing (Leonard and Sensiper 1998). In line with this phenomenon, networks become the basic idea of evolution in analysing system of innovation by stressing the idea of an accumulation of knowledge through external, integrated and extensive interrelationships between actors (Rothwell 1994).

In addition, the definition of an innovation network can be found, for example, through studies done by Omta (2002). He argues that innovation networks are a platform to circulate, explore, and accumulate knowledge and information as well as to actualize it into products or services that have a newness and added value to end-users. Subsequently, basic components of an innovation network include actors/nodes, links/edges/relations, and attributes/goals (Ahuja 2000). In addition, the relationship between actors can be direct and indirect (Ahuja et al. 2009; Ahuja 2000; Gilsing and Noteboom 2005). The composition of a network may also be either homogenous or heterogeneous (Ahrweiler and Keane 2013; Batterink et al. 2010). Moreover, there is also a possibility for an innovation network to be described either as group of many decentralized actors or as a unity of various participants that are led by a specific actor (Berasategi et al. 2011; Berseck 2018). Networks may vary in terms of duration, degrees of formality, geographical scope, and purpose that illustrate the variety in how to identify, distinct and compare them (Schön and Pyka 2012). In relation to the development of a new technological regime, it is explained that features of a network implicate a level of complexity of strategy as well as the potential of specific novel innovation that is going to be generated (Pyka and Scharnhorst 2009; Ahuja et al. 2009).

Furthermore, an innovation network can be analysed through the dynamics of collaborative movements within it (van Rijnsoever et al. 2015). The collaborative activities mainly have both short and long-term objectives.

- One of the most significant short-term goals of collaborations within innovation networks includes formation of linkages between individuals or enterprises to access complementary innovation assets and to allow them to stay competitive (Cantner and Graf 2006).
    - Innovation nexuses provide opportunities for companies to increase competitiveness by entering into relationships with their partners in order to gain both external material and immaterial resources. In the network they are able to search and explore new external knowledge (Gretzinger et

al. 2010; Hagedoorn 1993). Accordingly, collaborative actions within a network for innovation are also a strategy for organizations to gain access to a common infrastructure within the network and specific social-political support that is particularly available in the network (Scozzi et al. 2005). Social capital, prestige, value-added chains also belong to this benefit (Lengnick-Hall 1992).

  - Wu et al. (2019) also explain that collaborative innovation refers collaborative projects within the nexus that involve series of activities in order to complement each other's resource deficit as well as to share the outcome and risk together. They add that, in the end, participants may experience cost saving and less exposure to devastastion if the collaboration fails. Dyer & Nobeoka (2000) and Cheng & Chen (2013) also suggest that co-operation through a specific plaform is a solution for firms or organizations to access knowledge and other related facilities from their partners, while providing the same thing to their partners. Furthermore, they add that the process regarding to what extent a firm must cooperate with other firms depends on its eagerness and a consideration that its partners have the things that it is also looking for.
  - Aside from that, Hagedoorn (1993) argues that firms enter relationships with other firms in order to gain more experiences in the hope of accumulating tacit knowledge and skills, new ideas, access to a broader contact, funding, person-power (especially a highly specialized labor force), outsourcing a specific assignment, and the testing ability and compatibility of partners in undertaking the project.

- The long-term goal of collaborative innovation processes is to achieve resource integration or common values (Burt 2004; Beck et al. 2008; Berasategi et al. 2011).
  - According to De Groote & Backmann (2020) and Cantner & Graf (2006), partnerships within innovation network platforms mean the togetherness of firms and other stakeholders, including academics, government and intermediaries, that work to create a successfulness in innovation processes through knowledge and resource exchange. In the process, different actors may show a non-linear mechanism to develop innovation through in-depth collaboration and common resource accumulation.
  - Turyakira & Mbidde (2015) assert that the connection between actors may have the goal to create a voluntary relationship and unity whilst building a structure and a mechanism that provide resource integration and consensus to achieve a beneficial common goal.
  - Accordingly, Rehm et al. (2016), Schön & Pyka (2012), and Pyka & Scharnhorst (2009) explain that a collaborative network is about establishing co-operation through generating a common value in order to have a coordination and synchronization of actions of different actors so that innovation is created. They add that the functionality of a network is reflected through the speed of information circulation between actors and the willingness or capacity of actors to conduct reciprocal communication.

- In addition, Katz & Martin (1997) and Powell (1998) assert that co-operation for innovation is necessary in order to increase the scale of activity, for example by being involved in a network which is involving national or international partners and to increase the level of speciality or uniqueness or expertise, by adopting the principal of division of labor within the network or collaboration platform.

2.2.2 Types of Innovation network

Informal vs. formal network

An informal innovation network is mainly based on trust, common values or norms owned by participants (Hagedoorn 1993). The positive aspect of this network is that it may offer a higher level of efficiency in terms of resource allocation, information sharing, flexibility in terms of organization of linkages due to a lower degree of complication of bureaucracy and legal-institutional responsibility / sanctions or even rewards as consequences of activities (Ahrweiler and Keane 2013). However, the negative side of this network is that there is potentially a higher possibility of discrimination between participants and an inconsistency of actions and commitments of stakeholders because the task or responsibility is not formally given (Hemphälä and Magnusson 2012).

On the other hand, a formal network enhances the enthusiasm of stakeholders to participate because it offers the availability of a higher degree of protection towards intellectual and internal material property (Powell et al. 1996; Turyakira and Mbidde 2015). In addition, formal networks offer a defined direction and a higher level of controllability (Scozzi et al. 2005). The allocation of responsibility, conflict prevention and the elimination of distrust are applied in a formal network structure (Rehm et al. 2016; Pippel 2012). However, the formal network may reduce the flexibility of individual organizations in carrying out their non-routine activities, thus potentially hindering the exploration of new ideas (Leonard and Sensiper 1998). Transaction costs for coordination may increase in order to gain more transaction efficiency in formal networks (Kenis and Knoke 2002; Caniels and Romijn 2008).

Less innovative vs. innovative partnership

Bukhshtaber (2018) explains that partnerships can be broken down into several categories based on the characteristics of the interdependency among actors so that differences in terms of their output can be seen. He adds that less innovative partnerships can result from centralized and linear or sequential correlation among actors due to the priority placed on planning and control of the processes. Meanwhile Sandberg et al. (2015) argue that in order to be more innovative, the interrelationship between elements of the network should be reciprocal and team-like because those types of relationships enable two-sided or multi-sided communication for exploring and actualizing information. They also create joint-decision making as well as common values (Skeberdyte 2014).

Vertical, horizontal, and lateral partnerships

- A vertical collaboration consists of linkages between suppliers and consumers. It can be dedicated to consumers because the supplier would like to develop a new or customized product (forward linkage), or it can be a partnership in order to create or improve a specific material or component (backward linkage) (Bukhshtaber 2018; Boon et al. 2014).
  - Vertical collaboration refers to project-oriented co-operation within a similar chain nexus (Omta 2002).
  - Vertical collaboration may feature a hierarchical structure (Cap et al. 2019). It may happen that senior leaders supervise and provide their sub-ordinates the resources or knowledge to enhance the network (Diekhof and Cantner 2017). Due to their competitive position, for example in terms of financial or political support, actors that are at the top level of a hierarchy usually have the ability to provide legitimacy for the majority of stakeholders due to a positive publicity so that majority of actors can actualize their plans (Eidt et al. 2020; Engwall et al. 2021).
  - The risks are somehow relatively low due to a clear scope of competency between participants (Caniels et al. 2007). Further risks may also arise including a lack of trust and commitment (Camarinha-Matos et al. 2015). In addition, the availability of unfair senior leaders with their unfair domination can also prevent actors at the lower tier of optimally carrying out their collaborative projects (Chiaroni et al. 2019)

- Lateral collaboration in some examples refers to vertical collaboration with the ability to create links with third parties, for example research institutes, consumer protection boards, governmental bodies, firms from different industrial sectors and international initiatives (Bittencourt et al. 2020a).
  - This type of collaboration helps the partnership in developing products or components and gaining an image in society (Calia et al. 2007).

- The positive aspect of this collaboration is that participants can have a greater chance of enriching their resources that is beyond their vertical and horizontal types of collaboration (Camarinha-Matos et al. 2015).
- The risks may include a lack of trust with third parties and the pessimism of participants in gaining benefit from the collaboration as well as the complexity of the governance of the network (Capaldo 2007).

- Horizontal collaboration usually covers actions between firms in undertaking cooperation or transfer a specific amount of resources to the network while at the same time maintaining competitiveness and independency (Liu 2016).
  - The aim of a horizontal partnership is to create a win-win solution or complementary resources (Albuquerque et al. 2011).
  - According to Alpkan & Gemici (2016) and Andersson & Eriksson (2018a), when collaboration is carried out between firms that generate similar market products, then the risk and opportunity would be higher. They add that management for this type of collaboration is rather complex because it involves a strategy to deal with potential conflicts of interest, a lack of commitment during collaboration engagement, and strong but unhealthy competition. There is also the possibility for a strong actor to control,hinder or to acquire its partner using the collaboration (An et al. 2014).
  - Horizontal co-operations encourage joint investment on innovation, such as in the form of strategic alliances or joint ventures as well as to enhance a common agreement related to product standardization and advocacy to gain political support (Batterink et al. 2010; Bode and Simon 2011).
  - Horizontal and lateral partnership are riskier than vertical partnerships due to the complexity of components, the diversity of activities, and more costly in terms of coordination (Ahrweiler and Keane 2013).

Variety in term of duration and size of participants

A long-term collaboration is usually more beneficial, even though it may be exposed to a higher level of risks (Levén et al. 2014). A short-term partnership is efficient in handling specific problems, whereas a long term partnership creates greater opportunies of innovation through accumulating of common resources, strong interdependency and complex competencies (Liu et al. 2021). In addition, the number of participants can indicate the potential of common resource accumulation and the possibilities to escalate the collaboration (Muller and Peres 2019). The risk of having an increase in participant numbers is about the difficulties in managing them, because each participant may have its own objective and preferences (Pikkarainen et al. 2017; Nambisan and Sawhney 2011).

3 Building a conceptual framework: Innovation networks as pioneers of technological innovation systems (TISs)

This chapter is written to build a conceptual framework for the study. It begins with a literature review that explains the criticism of current literature of TIS due to the lack of bottom-up approach in examining the process of formation of system of innovation for a specific technology field and the limited number of studies about potential intervention of leading actors during the formation and implementation of the system, especially in the context of developing countries. Subsequently, there is a literature review about the importance of innovation networks as a specific subject of analysis due to its potential in creating and coordinating collaborative activities to function a TIS. In addition, discussions about the general strategy of developing countries, especially Southeast Asian countries, to handle disruptive innovations in the renewable energy sector, including smart grids, are explained in the chapter in order to enrich the conceptual framework. At the end of the chapter, the general potential contribution of the study to TIS literature by adopting concepts of innovation networks as basic indicators of the formation and operation of TIS functions is explained through its conceptual framework.

3.1 Criticisms towards a technological innovation system (TIS) approach and the research opportunity

The majority of TIS studies still focus on ''meso'' levels, paying too much attention to the structure of the system and its general functions (Walrave and Raven 2016; Mohammadi et al. 2013; van Lancker et al. 2016; Bento and Wilson 2016; Tigabu et al. 2015b). In most TIS studies, the structure and functions of a TIS are described at aggregate levels in order to find out the common symptoms (Musiolik and Markard 2011; Musiolik 2012; Binz et al. 2014). However, not much background explanation is given in order to understand how and why the structure and functionality of a TIS initially emerge (Musiolik and Markard 2011; Musiolik 2012; Binz et al. 2014). In addition, an analysis about what kind of a necessary long-term strategy that is required to manage the system until it reaches the growth phase is still needed in TIS studies (Walrave and Raven 2016).

Furthermore, Bergek et al. (2008c) assert that most TIS studies still lack a ''bottom up'' approach to illustrate the growing process of the system. They argue that the formation of a technological system does not automatically happen, but usually starts from small nexuses consisting of a limited scale of a group of entrepreneurs and others struggling to prove the importance of the novel innovations. They add that the process of small nexuses in gaining or losing political support and how they steer the direction of the new technology requires consideration. In line with that, Bergek et al. (2015) also argue that the characteristics of interlinkages between actors may influence the future of TIS. For example, a small collaborative network that consists of competent linkages between innovators and users may more easily create a political legitimacy than a network that is mostly occupied by universities.

In addition, according to Anadon et al. (2016), large parts of actual TIS studies still do not give an extensive explanation about focal actors that may provide significant contributions in directing the existence of the ecosystem of novel technologies. Simultaneously, based on their research about the introduction of new varieties of crops in a particular community in east African countries, they show that sceptical behaviours and interventions of several prominent leaders or actors from current technological regimes tend to either delay the formation of structures of a system of innovation of a specific and new technology because they challenge innovators to re-create innovation that is suitable for local needs, or cancel the formation of the system by maintaining the status quo. Sahin (2006) also argues that TIS studies are predominantly concerning investigations that do not provide a detailed exploration about the role of a specific and powerful group of actors, for example early adopters, in the evolvement of technological innovation systems, especially to learn about their interest and capacity in deploying resources to contribute to the functions of system of innovations. At the same time, Musiolik (2012), Kern (2015), and Musiolik & Markard (2011) also assert that most TISs do not just emerge by themselves, but are deliberately created and orchestrated by particular actors that have an interest towards a novel technology as well as prominent capacity in terms of economics, social life and politics.

3.2 Innovation networks as cells of system of innovations for a new technology field

Networks and linkages belong to basic elements in innovation system discourse beside actors, institutions and the existence of new technology artefacts (Bergek et al. 2015; Hekkert et al. 2007; Foxon et al. 2003; Kao et al. 2019; Markard 2020). For more than two decades, studies of innovation systems have either explicitly or implicitly describe that linkages between actors of innovation movements are very crucial to be taken care of (Rogers 1983; Jacobsson and Johnson 2000; Carlsson 1997; Gaziulusoy 2010). Even Freeman (1989) argues that system of innovation itself refers to platforms of interaction between actors and organizations either in the public or business sector which are aimed at acquiring, copying, re-designing and commercializing new innovations. Nevertheless, the actual use of a network as a specific perspective to explicitly explain potential and development progress of a technological innovation system (TIS) are somehow still rarely found in literature (Binz et al. 2014; Musiolik 2012; Musiolik and Markard 2011; Coenen and Díaz López 2010; Kastelle and Steen 2010). Nevertheless, Figure 3-1 describes a collection of keywords from various studies to create interconnection between innovation networks, actions done in innovation networks and system of innovation emergences. Those keywords depict the potential role of innovation networks as the ''embryo'' of a system of innovation.

One of the explanations about the interconnections can be found through research done by van de Ven (2005). He argues that a positively performing relationship among a small number of competent actors through various times and events can turn into effective collective movements that go beyond their initial endeavour because they can grow as a togetherness or '' to be together in packs'' that have such as institutional legitimacy in order to handle common challenges. To confirm this statement, Schön and Pyka (2012) explain that systemic innovation processes can happen through irregular and permanent patterns of modest, cumulative, original and harmonious developments of networks. According to them, the dynamic of interrelationships between members of innovation networks that are interpreted into actions of members, define the development process. Accordingly, Kogut (2000) suggests that networks can shape systemic innovation processes by accumulating common resources from multiple specialized firms and coordinate them, in which firms join them in order to enrich their own competitiveness and exploit network assets simultaneously.

Innovation networks

- platforms of interactions
- consist of various smaller work packages/ multiple local sub-networks/multiple coalition between heterogenous actors / teammates with different competency
- specific proportion of innovators, consumers, policy makers, universities as members
- possibility of having a leader or an orchestrator
- participation is usually voluntary
- competition and co-operation are the main objectives of members

Source: (Bogers 2011; Bush et al. 2016; Bush et al. 2017; Cipolla and Manzini 2009; Kivimaa et al. 2019; Manzini and Vezzoli 2003; Miller and Mobarak 2013)

Actions done within innovation networks

- dynamic relationship of competent actors as ‘’together in packs’’, evolves over time to create vicious/virtuous cycle
- formation of interdependence multiple small local sub- networks for implementing collaborative activities
- coordination and division of labor
- creation of ambassador/common manager/common leader /focal member of network that may orchestrate knowledge /information circulation

Source: (Bento and Wilson 2016; Powell et al. 1996; Suurs 2009; Verbong and Loorbach 2012)

Emergence of systemic innovations

- longevity in process of accumulation of network resources
- long-term various collaborative innovation activities that have common vision
- network for production of new value, creation of business opportunities, sharing of common fix asset/permanent facility
- irregular but permanent of modest, cumulative, and original co-evolution of network to change current technological regime
- deepening multiple ties, competitiveness, higher ‘’advocacy coalition’’, and conducive economic-social regime for novel technology

Source: (Freeman 1989; Gaziulusoy 2010; Jacobsson and Johnson 2000; Kanda et al. 2019; Nilsson and Sia-Ljungström 2013; van de Ven 2005)

Source: Author’s compilation

Figure 3-1 Keywords depict potential relationship between innovation networks, action done within innovation networks and emergence of systemic innovations

Similarly, Carlsson & Jacobsson (1997) also assert that an ecosystem for innovation is made up of networks and social-economic-technical situations which grow moderately in order to provide the formation of market-positive externalities as well as to assist stakeholders in term of uncertainties. They add that networks may experience failures in growth due to a weak relationship between actors or are orchestrated in the wrong direction by either unfair policy makers or incumbent firms, or are too weak to gain advocacy. To elaborate this statement, Wesche et al. (2019) and Suurs (2009) explain that networking and interrelationships between actors are indeed the main indicators to determine the potentials of a system of innovation in order to turn into either a ''vicious cycle'' or a ''virtuous cycle''. Subsequently, through analysing two innovation networks' actors in food sectors in Sweden and Denmark, Nilsson & Sia-Ljungström (2013) show that networks for innovation can be scaled up to cover complex and systemic activities if the networks own longevity in term of the accumulation of common facilities/assets/infrastructures, so that they can create business opportunities and have long term relationship-goals.

Business, knowledge, and intermediary-based innovation networks

Innovation networks that function to handle systemic activities may be born out of different backgrounds and work for different objectives (Cantner and Graf 2006; Gretzinger et al. 2010). van Rijnsoever et al. (2015) and Powell (1998) explain that each collaboration arrangement for enhancing innovation processes is conceivably unique or very specific in terms of their priorities, main goal,and structure. In line with this statement, studies about innovation network, for example which are done by Janssen et al. (2018), Berglund & Sandström (2013), and Wu & Wu (2012), depict three different types of networks that conceivably contribute to the functionality of a TIS. Those include business networks, knowledge networks, and intermediary-based networks.

Business networks may exist only between firms (innovators) because they are aimed at either exploring or reconfiguring niche technologies by exploitating network resources dedicated to novel innovations (Pushpananthan 2022). Business networks also can consist of interrelationships between innovators and facilitators, e.g., government, NGOs or universities, that aims to access funding opportunities or policy support as well as to circulate knowledge (Haus-Reve et al. 2019). Linkages between innovators and end-users are also conceivably built within business networks, when the novel technology reaches commercial stage (Mao et al. 2020). Meanwhile, knowledge networks have a high possibility to have only interrelationships between universities and facilitators, namely government, without directly involving end-users and industry (Leon and Martínez 2016). This happens when the novel innovation is newly introduced and needs to be further investigated (Wu and Wu 2012). At the same time, intermediary based-networks may have two features: 1). It exists only between users and intermediary, because the innovation is a certain technology that refers to an alternative solution of problem in society and it is necessary to be introduced to end-users through acknowledgement given by specific parties, e.g., government, group of individuals, or mass-media (Ivan Pellegrin et al. 2010).; 2). It covers relationships between innovators, users and facilitators because the novel technology is still in the form of prototypes that are required to be tested in actual situations with significant support from facilitators, especially government (Howells 2006). For more details, Table 3-1 provides information about the attributes of business networks, knowledge networks and intermediary-based networks.

Table 3-1 Specifications of business networks, knowledge networks, and intermediary-based innovation networks

Description	Business network Source: (Berglund and Sandström 2013; Haus-Reve et al. 2019; Mao et al. 2020; Pushpananthan 2022)	Knowledge network Source: (Wu and Wu 2012; Albuquerque et al. 2011; Bedford et al. 2018; Howells et al. 2012; Leon and Martínez 2016)	Intermediary-based innovation network Source: (Hermann et al. 2016; Howells 2006; Ivan Pellegrin et al. 2010; Janssen et al. 2018)
Aims	• members join, cooperate and compete simultaneously • aims for creating interdependence, network resource accumulation, network resource exploitation and co-creation • can exist in a specific geographical area (clusters)	• aims for knowledge generation and knowledge sharing with the possibility of realizing it into a business • activities can be done in a specific infrastructure, for example innovation incubators or technological science parks that belong to universities	• has a specific goal or background, for example for innovation diffusion in specific communities or geographical areas • usually as a part of national top-down innovation program which is led by government, or grass-root movements which are facilitated by non-go-vernmental bodies or individual organizations
Leader/Initiator/Orchestrator	Prestigious or powerful incumbent firms or start-up firms	University/research centres	Intermediary bodies: government bodies or NGOs or individuals
Type of participants	Firms, consumers	Universities, research centres, start-up firms, communities	Communities, government, firms, universities
Connectivity	• based on trust or voluntary participation • is possibility orchestrated by large and powerful actors, for example incumbent firms or international innovators	• majority of linkages are non-competing relationships • high level of density but tends to be a homogenous network	• governance of network depends on type of intermediary. • networks led by governments or specific expert orga-nizations may give less in providing room for consensus among participants than networks led by independent-non- profit organizations or communities

Source: Author’s compilation

3.3 Innovation networks: Their phases in terms of resource orchestration and the potential to scale up into innovation systems

Networks are often seen as complex adaptive configurations that consist of a broad range of organizations and diverse relationships, in which each body tries to achieve its own goals (Ahuja et al. 2009). Bittencourt et al. (2021) assert that orchestration refers to a portrait evolvement and organization of actions undertaken by networks. It is aimed at augmenting the innovations through enabling the congregation and synchronization elements of network with the help of careful direction and influence. In this stage, orchestration exists in term of deliberate and interrelated actions and measures to enable the performance of collaborations that aim innovations (Pikkarainen et al. 2017).

Resource orchestration in current TIS studies

Successful innovation processes are an output of non-stop adjustments, which sometimes take a long time, multitasking and slow in the process (Rabelo et al. 2015). It may also evolve through various stages of coordination or orchestration in order to be mature (Bento and Fontes 2016). Nevertheless, there is still limited TIS literature that explicitly describes the orchestration process of heterogenous elements of innovation activities until they emerge as a single running system (Musiolik and Markard 2011; Bittencourt et al. 2020b). In transitional theories or in TIS studies, orchestrators are by some means narrated as innovation intermediaries (Todeva 2013; Batouk 2015; Kivimaa 2014; Nilsson and Sia-Ljungström 2013; Mignon and Kanda 2018).

Innovation intermediaries tend to be referred to as resource orchestrator-facilitators. The role of facilitators, such as providing strategic policy, visions, programs, and technical standardization, were mostly done by governments (Kivimaa and Martiskainen 2018; Schiefer and Rickert 2013). In addition, various intermediary functions, especially for funding facilitation, information brokers, stakeholder meeting platforms, were also run by specific agents or bodies, for example agents for technology diffusion or innovation support, that could be formed by either governments or private firms, or both (Dalziel 2010; Abbate et al. 2015; Ahsan and Malik 2015). Studies about intermediaries mostly focus on their role in certain periods of time. Clayton et al. (2018), Winskel et al. (2014), Wang & Wang (2016), and Bush et al. (2016) for example, emphasize their studies on the role of intermediaries in enhancing innovation processes which are mostly within a limited period of time, without any explicit and comprehensive exploration of their motivation, background, scaling up capacity as well as their long-term strategy in order to maintain sustainability and synergy of innovation processes.

Meanwhile,Kivimaa & Martiskainen (2018) and Kivimaa et al. (2019) assert that the evolution of system of innovation starts from the existence of innovation intermediaries or governances at grassroot levels or, in this case, in places among and between users or demonstration projects. Governance at a grass roots level consists of a planning and implementation phase. In addition, the administration of different grass root projects tends to evolve, accumulate, and be grouped vertically at a meso level in the form of a specific innovation network. A specific innovation network tends to have leading actors which act as the resource manager or intermediary. The ideal category of intermediary is a common manager at the systemic level. It builds correlation among different actors from multiple networks due to a common vision and aims to facilitate a technology transition. However, Kivimaa & Martiskainen (2018) and Kivimaa et al. (2019) focused on a limited number of facilitators without comprehensively exploring the possibility of resource management at various levels of the innovation processes through a consensus among stakeholders.

Different phases of resource orchestration undertaken by innovation networks to create a system of innovation

Presutti et al. (2013) argue that orchestration of an innovation network so that it can handle more complex tasks, especially in the form of industrial clusters, can be divided into two stages: emergence and growth. They argue that emergence phase is indicated by unstable, uncoordinated and uncertain conditions in terms of relationships between the members of innovation networks, whereas the growing phase refers to the stage where the knowledge or value of networks is already accumulated, implemented and further evolved. Accordingly, Bittencourt et al. (2021), Pikkarainen et al. (2017), Fonti et al. (2015), and Dhanaraj & Parkhe (2006) argue that in the emerging phase, resource orchestration is seen in terms of identifying or structuring the potential of the network. Target, vision and goal setting of innovation activity are determined in this phase either by a limited number of actors, or maybe through consensus. Communication between stakeholders for determining or imposing visions is critical in this level. Identification of the expertise and motivation of each stakeholder in joining the network is carried out in this phase. Subsequently, in the growth phase, grouping or determining projects as well as its executors take place (Phelps et al. 2012). Beside bundling the resources, in the growth phase, resource orchestration can be found in the form of network leveraging through actualizing the market potential as well as maintaining and improving the relationship among stakeholders (Shukla 2020; Bittencourt et al. 2021; Boss 2014; Dhanaraj and Parkhe 2006). In this level, a network is necessary to be kept stable, synchronized, and has better chances to produce innovations (Sirmon et al. 2011).

Furthermore,Chen et al. (2019), Golub et al. (2019), and Autio (2021) assert that the process of scaling up a system of innovation or ecosystem for innovation could be indicated through dynamic capability in orchestrating the resources between multiple programs through several stages. They argue that the first level of orchestration is called environment scanning and it has the objective of determining the existence of networks through contact building as well as knowledge sharing and co-operation building so that they can run projects together. In addition, the second phase of the development of an innovation ecosystem is named as the commitment of stakeholders in formalizing their network, expanding activities and resources and sophisticating the resources within the network (Chen and Schwartz 2013; Chen et al. 2019). The third phase is called ''value integration'' because it is a time where the market potential for the innovation has emerged and stakeholders focus on discussing topics related to market competition, market incentive, and new business models (Chen et al. 2019; Golub et al. 2019). Based on his study about innovation networks in the electricity sector in China, Chen et al. (2019) argue that all players can together build the innovation ecosystem by forming symbiotic relationships through ''co-learning'' and ''co-evolving''.

Meanwhile, according to Musiolik (2012) and Rabelo et al. (2015), not all innovation networks could complete an exact resource orchestration. It means that not all innovation networks have the potential to experience different evolutionary phases in order to grow into a systemic one. It is possible that movements within the networks are discontinued or are not long-lasting. They argue that it depends on the conditions of basic motivations as well as the size and structure of members. According to them, there are networks that are capable of accumulating common network resources, and thus required resource orchestration because they operate in handling more demanding resource mobilization and multitasking topics.

3.3.1 The mode of resource orchestration, network attributes and the evolution of networks to grow into a technological innovation system (TIS): Dominant orchestration vs. consensus-based orchestration

Beside the phase of orchestration, the mode of orchestration may also determine the potential evolution of innovation networks to function at a systemic level (Chiaroni et al. 2019; Musiolik and Markard 2011). According to Batista et al. (2021), Boss (2014) and Toigo et al. (2021), the orchestration of innovation networks is one of the approaches to facilitate mutually advantageous collaborations within a network so that those collaborations develop optimally in various stages of the innovation process. There are two basic approaches in conducting network orchestration, namely closed and open orchestration. Closed orchestration is aimed at managing resources at multiple phases of innovation processes by emphasizing the existence of hierarchical structures (Hurmelinna-Laukkanen et al. 2022; Dhanaraj and Parkhe 2006; Pikkarainen et al. 2017; Hurmelinna-Laukkanen and Nätti 2012), whereas open orchestration refers to the organization of network properties by stressing the importance of consensus among stakeholders (Ferraro and Iovanella 2015; Chen et al. 2019; Cap et al. 2019; Hossain 2012; Liu and Rong 2015).

Dhanaraj & Parkhe (2006) are among scholars that uphold the idea of dominant resource management for innovation networks. They portray an innovation network as a unit consisting of weak, integrated but independent elements that possesses unstable connections among its elements. They add that it often lacks hierarchical authority and explicit strategic choices but it indeed potentially experiences a ''discreet leadership''. Furthermore, they elaborate that the characteristics of network orchestration can then be analysed in the time of recruitment activities, where a potential and influential actor, due to its central position and prominent status, conceivably intervenes in the diversity of members as well as the size of activities carried out within the network. In line with that, Pikkarainen et al. (2017) explain that network orchestration is a deliberate action conducted by a single entity or a few focal actors in order to create and nurture the development of the network and the collaborations inside it. Those focal actors pioneer various activities, determine vision and control the distribution of resources within the network (Hurmelinna-Laukkanen and Nätti 2012). Marquis & Tilcsik (2013) and Lawson-Lartego & Mathiassen (2016) also add that ''focal entities'' exist to dominate networks because they are already prominent in terms of resources and tend to continue to maintain their power even though the ecosystem is changing in sequential periods. Even when the innovation is radical, prominent actors are persistent to design and dominate the network because stakeholders of the network have a high dependency on them in terms of vision, experience, knowledge, finances, and networks (Hurmelinna-Laukkanen et al. 2021).

In contrast, Berseck (2018) and Reypens et al. (2021) argue that the orchestration of innovation networks is a negotiated agenda among members since the participation in the network is voluntary and based on trust. Berglund & Sandström (2013), through using a firm as an illustration of a network to explain the process of resource orchestration, attest that orchestration refers to a performance of a firm in creating and running different evolving business units which have undergone multiple interdependent activities. They add that in the process of the orchestration of its resources to deliver or to embrace a beneficial value, the firm may face difficulties in managing its resources to solve tensions between old and new business units. They argue that when the firm or the main headquarter lacks leadership, then ''the open system perspective'', (where the firm is forced to perform to serve various partners in business units because the resources of the firm are dispersed to those units), is proposed. They also suggest that the firm also tends to build contacts with surrounding partners from different business units in order to decrease uncertainty or conflict in a neutral way. In addition, Golub et al. (2019) explains that it is extremely difficult for a sole actor to control the network that comprises of diverse cooperation platforms with a high degree of member's heterogeneity and a high level of specificity. In other words, for a network with a high numbers but with a low diversity of membership, dominating orchestration might be effective. In contrast, in conditions where a network consists of various types of collaborations and expertises that are distributed among different partners in various groups, the dominant actor may face difficulties in understanding all the knowledge of all members (Busquets 2010). In this context, dominant network orchestration would be ineffective.

To summarize, whether an innovation network experiences dominant resource orchestration or consensus-based resource orchestration, it can be distinguished through several aspects, including aims, the formation process, power distribution, and resource deployment (See Table 3-2). Innovation networks that undergo dominant orchestration are seen to be specialists in handling particular tasks which are mostly to be completed in a short-term period (Musiolik 2012). In addition, dominant resource administration refers to a high dependency on a limited number of powerful actors (Dhanaraj and Parkhe 2006). In this type of resource orchestration, networks work as a means to complete a certain goal and tend to have a low diversity in terms of expertise or values among members (Hurmelinna-Laukkanen and Nätti 2012). To plan, coordinate and control each step of the project implementation undertaken by network members are among actions of those powerful actors so that the network can eliminate the uncertainty and achieve the desirable output (Ferraro and Iovanella 2015). Furthermore, dominant resource management in innovation networks depicts a condition of networks which lacks a long-term vision because it only focuses on completing the temporary agenda of a limited number of stakeholders (Hilmann et al. 2011).

On the other hand, innovation networks which deploy consensus-based orchestration are depicted to have a more complex composition of stakeholders as well as types of innovations that could be achieved (Reypens et al. 2021; Ritala et al. 2009) (See Table 3-2). Instead of significantly being influenced by the geographical proximity among its members, those networks prefer to enhance the creation of virtual interconnection based on trust and availability of a common facilitator (Bittencourt 2020). They also provide opportunities for members in a more flexible way to combine or use resources in the network in order to implement their common goals (Mutsaers 2015). Even though a complex system with concensus-based resource orchestration is required to cover the high cost for coordination, it shows the potentials of innovation networks to facilitate relationships among the diversity and dynamics of members in a more adjustable way, therefore the networks have greater chances to last longer (Nambisan and Sawhney 2011; Musiolik and Markard 2011).

Table 3-2 Different characteristics between dominant and consensus mode of network resource orchestration

Elements to identify	**Dominant orchestration** Source:(Hurmelinna-Laukkanen and Nätti 2012; Dhanaraj and Parkhe 2006; Musiolik 2012; Ferraro and Iovanella 2015; Hilmann et al. 2011)	**Consensus-based orchestration** Source: (Bittencourt et al. 2020b; Ferraro and Iovanella 2015; Liu and Rong 2015; Chen et al. 2019; Mignoni et al. 2021; Musiolik and Markard 2011)
Definition of the network	• Network as a means, where spatial proximity is quite important. • Network is set as a tool to facilitate short-term relationships among a limited number of members in order to achieve a specific goal.	• Network as the objective, where virtual organization is more desirable. • Network is seen as a stable platform to facilitate dynamic relationship among multiple members.
Goal of the network	• to complement assets/resources between members in order to accomplish a specific task • to command/guide/build a specific connection. • not a very complex system of stakeholders.	• to accumulate and develop resources of the network so that strong systemic networks can be formed • to influence many stakeholders in a rather complex system
Formation of network	• initiation process done by a single member or a few members of a network • resources used for building network are from a specific or limited number of actors • members' recruitment is restricted; based on a specific evaluation of initiator(s) • members' engagement is enforced contractually	• initiated through an agreement by a majority of members of a network • resources used for forming networks came from multiple members • participation in the network is voluntary
Planning, control and trust within the network	Planning and control are fundamental, trust is advisable.	Trust is most fundamental, planning and control are commendable.
Hierarchies, authority and coordination within the network	There is someone who has the highest authority that coordinates the cooperation, even though the hierarchies are minimized	There is a need for someone with highest authority or capability in order to facilitate cooperation.
Deployment and combination of resources within network	• Restricted, directed, and centralized coordinated • All of the assets/resources are mostly under control of the network initiator(s) • Benefits of collective output is distri-buted through negotiation	• The accumulated assets are under control of the network. • Network facilitates decentralized and independent activities of members

		• It is more flexible for the members to have benefit of or to deploy the shared assets in the network.
Project coordination and implementation within network	Members do not have a high dissimilarity of resources; uncertainty is not that high but possible co-creation is not that high.	Diversity of resources among members is high, transaction cost is not small, coordination is costly, high level of uncertainty, but possible innovation created is conceivably high.

Source: Author's compilation

In order to correlate the mode of resource orchestration with potential the evolvement of innovation networks, Nambisan & Sawhney (2011), Musiolik (2012), Ferraro & Iovanella (2015), Chen et al. (2019), and Liu & Rong (2015) assert that the more importance placed on consensus in organizing accumulated resources within a network, the more solid, more competitive and more stable the network to utilise its potentials in order to run systemic innovation processes, and vice versa. Bittencourt et al. (2020a) and Boss (2014) also argue that under consensus-based orchestration, members own the same rights to voice or to intervene the network. In line with that, Boss (2014) suggests that the maturity phase of innovation networks equal to the successful formation of a technological innovation system (TIS). He explains that the final stage of development of innovation nexuses enhances different stakeholders to act towards common visions by allowing them to discuss and utilize their common accumulated resources freely. Accordingly, Kivimaa et al. (2019) mention that a system of innovation refers to the ability of various stakeholders from multiple collaborative arrangements, coordinated by a common system resource manager, to provide a general forum for consensus and create spaces for disruptive innovationsby allowing the various involvement of on-site demonstration projects and early adoptions to grow independently so that technology transition happens.

3.3.2 Possibilities to have a hybrid resource orchestration mode

Fonti et al. (2015), Reypens et al. (2021), and Ahsan & Malik (2015) argue that even though having consensus resource orchestration may be a good indicator in describing a high level interconnectedness among elements of an innovation ecosystem, in some cases, it is possible to implement more than one resource orchestration style simultaneously in order to optimize performance of the elements. In line with that, Musiolik & Markard (2011) state that having consensus-based orchestration could be an important achievement of an innovation network to grow into a more complex entity as long as at the same time it also develops its relational resources. They elaborate those relational resources are about the ability of an innovation network to not only connects its members, but also builds its own competitiveness in industry or society through having reputation, power or legitimacy in terms of economic influence, and strong channels for building communication with politicians. Nevertheless, they explain that due to heterogenous specialities and the limited capacity of members, it seems too idealistic and takes a long time to accumulate those resources. They then suggest that in order to survive, potential innovation networks may function by implementing the consensus of their members but at the same time depending on a limited and specific number of powerful members in their network which already possess those relational resources.

In addition, Bittencourt et al. (2020b) and Mignoni et al. (2021) assert that a hybrid orchestration or co-orchestration is especially required for networks when dealing with a larger diversity of members and a high complexity of relationships between members. Reypens et al. (2021) also explain that it is possible for both dominating orchestrators and network consensus to exist together to operate the network in a certain period of time. They propose that the dominating actors stimulate relationships among members as well as communicate the network structures and goals to all members, while at the same time, members are required to build consensuses among themselves for matching their own interest in order to enhance collaborations at a grass-roots or micro level. Correspondingly, Cunningham & Cunningham (2007) state that in the emerging phase of innovation networks, a limited number of project initiators have an important role in developing conditions at a network level but experience a lack of adequate capacity in intervening in the autonomy of each member. They then assert that in order to build up a systemic cooperation, focal actors and consensus built by overall members should be able to work together side by side.

3.4 Existence of leading actors and its impact on network resource orchestration and the functionality of TIS

3.4.1 Strong vs. weak innovation networks: Implication for leading actors

In the literature of diffusion of innovation, the structural characteristics of linkages of among actors is crucial (Granovetter 1983; Dearing and Cox 2018; Kwon 1990). It may shape not only the environment of networks for technological diffusion, but also the behaviour of focal actors or opinion leaders (Wang 2017; Zhu et al. 2016; Turnbull 1980). Furthermore, Valente & Davis (1999) argue that modification of the network structure may be required if it is crucial to increase productivity. The structural situation of a network refers to all relationships that exist in the network, these are indicated through: direct and indirect ties between actors, the position of each actor between at least two other actors, and the performance of each actor. Some studies focus on developing analysis in order to trace the appearance of opinion leaders, the structure of information circulation and the strength of connections between actors (Trepte and Scherer 2010; Serdar Ozkan and Eda Ökten 2015). They stress the importance of the centrality of a leading actor in a situation where a leading actor is crucially important and is required to shape the network. In this stage, a leading actor is described as a player which owns rich resources to facilitate innovations, currently enjoys a strategic position in its current business or political network, and is the first elite to be attached to the new innovation (Vodopivec et al. 2021; Gnambs 2019; Karaca and Uyar 2014).

Each actor has its own level of centralistic position based on a number of actual links that it owns in the network (Muller and Peres 2019). If a particular actor has a degree of centrality that is tremendously higher than the rest of actors, it depicts that the network is highly centralized, and vice versa (Shaw - Ching Liu et al. 2005). The position of a leading actor is characterised by its well-connected situation to all actors because it shows its significance in the network through its central position (Zhu et al. 2016; Valente and Davis 1999). In addition, the power of a leading actor can be identified through its ability to control communication within a network by having other actors directly connected to it as well as its capacity to be a middleman between two groups of actors or two significant actors (Trepte and Scherer 2010; Wang 2017). The more centralized a leading actor, the higher rate of leading actors to rapidly orchestrate information circulation within the network (Reksulak et al. 2008).

In social network analysis, the value of the network density also plays a crucial role since it indicates the strength of interrelationships among members (Ahuja 2000). Network density is calculated through dividing the number of actual links by the number of potential links of the network (Gnambs 2019; Gilsing and Noteboom 2005). The higher the value of network density reflects a higher intensity of communication, participation, cooperation or interdependency in relationships among heterogenous parties in the network (Abbate et al. 2015; Bauer and Flagg 2010). In a closed network, high density indicates trust or contractual agreement, e.g. intellectual property contracst, in order to share the benefit or risk due to engaging relationships that later creates a type of common identity (Kulkov et al. 2021; Huang et al. 2020a). Furthermore, Rost (2011) suggests that a high network density has a positive correlation with the amount of influence of the most central figure in the network because the situation potentially produces a lack of power balance among members.

To avoid negative consequences of having too much centralized nexus, Fang et al. (2019) and Gilsing & Noteboom (2005) assert that diversification of activities within a network may create a more decentralized system or less dominated network that provides less room for the central actor in controlling the distribution of information or benefit sharing due to interactions. However, the disadvantage of a decentralized network is that the intensity of contact between members is rather weak (Lahiri et al. 2019; Michelfelder and Kratzer 2013). To elaborate more about the importance of a less centralized network, Ritala et al. (2009) explain that weak ties due to a more distributed subnetwors somehow have a correlation with bridging ties. It means that weak ties open up the possibility of new information flow from outside the network or from other alternative central actors to flow within the network, thus enhancing a higher level of creativity. Weak ties also test the trust of members in receiving information in the network (Kwon 1990).

3.4.2 Leading actors and dominant network resource orchestration

While there are discussions about consensus orchestration as the ideal way in managing the evolution of an innovation network, studies also show that various innovation networks happen to have a dominant orchestration in various steps of their development process (Bittencourt et al. 2021; Reypens et al. 2021). Aksenova (2020), based on her study about the digital industry in Finland, asserts that the open orchestration mode for inducing innovation systems, especially for technology intensive sectors, may not be effective without the availability of incentives and direction from a specific focal actor to attract other potential actors to join and create value within the network. Hilmann et al. (2011) argue that collaborations which are aimed at tackling a certain specific task with a restricted time schedule, limited resources and a limited number of involved participants would not easily move to the level of consensus orchestration. Accordingly, Musiolik (2012) explains that dominant orchestration occurs in networks that are identified without visions to undertake scale-up and overcome complex innovation processes. Those networks tend to put resource management as non-priority issues due to a high dependency on, and control from, a limited number of resource providers. Project specific networks or short-term technical or fiscal committees belong to this category.

In addition, descriptions about dominating orchestrators can be found in several studies as follows:

- The best dominating orchestrators consist of stakeholders which have the ability to do political lobbying and to be representative of leading companies (Musiolik and Markard 2011)
- Kivimaa & Martiskainen (2018) stress that only long-term prominent actors could act as intermediaries in networks consisting of various sub-intermediaries or facilitators which manage the diversity of activities at a micro level. Those actors have the capacity to stabilize the network by providing resources, setting rules and dominating other stakeholders at the same time. A prominent player controls not only at an upstream level, but also intervenes or participates in activities at a niche level.
- Significant orchestrators could be a body, especially from the government, that is able to create a high dependency of other stakeholders towards them because they deliver resources at almost every step of the innovation process (Kivimaa 2014). In the beginning they articulate the vision, build networks, and invest in various activities under a certain program (Cairney and Geyer 2015). As the network operates, they participate side by side by promising long-term agendas and facilitating learning activities (Bittencourt et al. 2021).
- Universities may also be able to pioneer innovation ecosystems through knowledge agglomeration and collaborative arrangements by creating science parks, technology incubators or technology transfer centres (Bedford et al. 2018; Cai et al. 2020a; Ferguson and Fernandez 2015; Ozkaya et al.).
- Chen et al. (2019) argue that within a collaborative ecosystem in an industry, there are hub firms that are powerful and able to afford authority and efficacy to pursue their goals. They add that hub firms tend to take control of the construction of the network by imposing regulations or values so that they are always able to reap the benefits beyond the complexity and high costs due to governing various stakeholders. In general, the goal of hub firms is to boost the network as well as to achieve more benefit due to its expansion (Cai et al. 2020b; Kenis and Knoke 2002). In order to do so, nurturing the network while maintaining their legitimacy is also required (Bittencourt et al. 2020a).
- Shukla (2020) adds that prominent or experienced focal builders increase the success of the resource bundling process. Using the case of business units in the film industry, Shukla (2020) found that business units that own a powerful leader would be able to gather a good quality of actors and other related resources in order to implement successful movie projects. In other words, the availability of an attractive and influential figure in the network would also likely increase the enthusiasm of other actors to participate more.

3.4.3 The role of dominant orchestrators

Dhanaraj & Parkhe (2006) argue that a focal actor, as a dominant orchestrator of an innovation network, has a challenging role in increasing innovation outcomes of its network. It is important for a focal actor to enhance knowledge circulation as well as to increase the competency of its network. Socialization and enhancement of learning between actors from different background organization through various channels of communication are key (Nambisan and Sawhney 2011; Levén et al. 2014). In addition, the focal actor is also responsible for building and maintaining trust among stakeholders as well as establishing the rules of the game, especially in governing the appropriability of innovation (Reypens et al. 2021). Network stability and sustainability is also a concern for a focal actor (Toigo et al. 2021). In a situation where the network is derived from less legal-formal arrangements, network instability may occur, for example, because a significant number of stakeholders leave the network or decrease their level of participation. In this case, the focal actor may react by maintaining its integrity, improving possible long-term cooperation, and developing a variety of relationships among stakeholders (Dhanaraj and Parkhe 2006; Hurmelinna-Laukkanen and Nätti 2018; Bittencourt et al. 2021).

Due to various types of position within the network, the availability of dominant actors may influence the network differently. There are specialist, superior, and commanding orchestrators that are termed players of the networks and are aimed at gaining competitiveness and profit for being in the networks and being able to control other members as well as attract potential members because of their resources (Nambisan and Sawhney 2011). In this situation, orchestrators may act as architect, asset providers and directors of networks (Pikkarainen et al. 2017; Hurmelinna-Laukkanen and Nätti 2012). In addition, there are also actors which have the goal of maintaining well-being and growing ideas of mutual cooperation in the networks (Hurmelinna-Laukkanen and Nätti 2018). They tend to be neutral with less motivation to gain monetary benefit. A provider of platforms for knowledge sharing also belongs to this category. The latter type of orchestrator is sponsors. They act as investors of collaborations within networks or act as middlemen between the executor of collaborations and financial entities (Batterink et al. 2010).

Simultaneously, dominant orchestrators may create a negative side effect on the network's health because their interventions can produce a significant disparity of resource distribution among stakeholders (Aksenova 2020). Furthermore, Kenis & Knoke (2002) assert that dominant orchestrators, for example intermediaries or large companies, deliberately build network platforms to maintain their power and status by using them for recruiting members whom they can control. By doing this, vertically integrated structures may remain in order to limit the potential development of innovative business ecosystems. Gawer & Cusumano (2014) add that self-centred orchestrators unfairly control a large number of nodes within an ecosystem, thus ma-king the ecosystem unstable and vulnerable. Designed innovation ecosystems may fail when the dominant orchestrators do not provide an opportunity for members to have a space for creativity, coalition and negotiation (Jacobides et al. 2018). Furthermore, innovation systems fail to emerge when orchestrators lack the leadership capacity as well as the expertise to articulate the values within network (Autio 2021).

3.4.4 Government as the main network orchestrator

One of the most classic arguments in correlating government and innovation is through the existence of government support to shape the structural elements of innovation systems by issuing strategies to encourage industry-university-government collaborations (Anadon et al. 2016; Suurs et al. 2010; Markard et al. 2009; Van Mierlo et al. 2010). As a potential orchestrator in creating and governing interactions between universities and companies, government starts by facilitating knowledge commercialization programs or research contracts for both parties (Baerz et al. 2011; Almeida et al. 2010). Aside from that, incentives, direct support, or subsidies from the government, and the protection of intellectual property rights are conceivably helpful to improve cooperation among various stakeholders in accelerating innovation processes (Breitinger et al. 2020; Fan et al. 2008). No matter the type of policy, it needs to open various possibilities, especially new entrepreneurs, to strengthen political legitimacy, create a new and competitive business ecosystem or system change, and have better and compatible infrastructures (Isoaho et al. 2017; Bergek et al. 2008a; Mignon and Bergek 2016).

Furthermore, each government may have its own focus for its innovation programs. Jacobsson & Bergek (2004) assert that innovation policy needs to first identify and understand the strengths and weaknesses of the field that requires intervention. The main goal should then be to either reduce blocking structures or increase the existing competitiveness. For example, between 1970 and 1990, Japan and South Korea focused on enforcing its innovation policy to encourage inter-sectoral scientific collaboration dedicated to projects for basic research, especially in the sectors of biotechnology, electronics, information, and material science (Harkola and Greve 1995; Stephan et al. 2017). On the other hand, from 1986 to 1995, China used its innovation policy to push research activities to catch up with current technological development in the market. China did this by reforming institutional conditions to ease and encourage collaboration between universities and companies (Cirera and Maloney 2017; Gosens and Lu 2013). To increase the efficiency of the policy, in 1999 China allowed universities to commercialize their inventions as well as providing them with intellectual property protection (Baerz et al. 2011; Boeing 2020). While the choice of policy focus of each government may vary, several studies emphasize that the capacity of governments to make the policy effective and efficient is the highest priority (Hasselbalch 2017; Rechsteiner 2021; Burke and Stephens 2018; Boeing 2020; Baerz et al. 2011). To explore this, studies divide the style of government in orchestrating their support for new technology into two approaches; top-down and bottom up (See Table 3-3).

Table 3-3 Top-down approach versus bottom-up approach to orchestrate innovation networks

Element	Approach	
	Top-down Source: (Davidson et al. 2017; Gallop et al. 2021; Guimon and Agapitova 2013; Ouyang et al. 2020; Jacobsson and Bergek 2004; McEntaggart et al. 2020; Callander and Matouschek 2021)	**Bottom Up** Source:(Fan et al. 2008; Leydesdorff 2005; Bittencourt et al. 2020a; Huang et al. 2020b; Numata et al. 2018; Möttur et al. 1978; Brem and Wolfram 2014)
Key player	Policy maker	Consumers or scholars or firms
Goal	Defined objectives	Unclear goal for the policy maker at first
Focus of implementation	Optimizing the right target	Building strong actualization or utilization of idea or goal comes from grassroot level
Evaluation criteria	Based on formal defined criteria	Level of relevant between evolvement at grassroot level and policy issue
Output	Emphasis more on structure of elements of the defined target	Emphasis on level of utilization or innovativeness
Advantage	Defined resources or instruments	Increases legitimacy of decentralized innovation activities and participatory governance
Disadvantage	Domination of policy maker might hinder or ignore opinion of majority of stakeholders, thus decrease goodwill of stakeholders to participate	• Budget are distributed into a small-scale activities that in some point might lack of coherence or focus. • Networks or relationships among stakeholders might be unstable due to problem related with trust, asymmetric distribution of benefit, and a lack of sui-table partner.

Source: Author’s compilation

3.4.4.1 Top-down approach to orchestrate innovation processes

Governments usually orchestrate mission-oriented projects or ''need to do'' projects based on top-down approaches (Suntharasaj 2013). Most of these projects are defined and funded by authoritative government offices, and are then implemented from a top national level to local actors. Because of this, the government dominates the development of those activities in order to control their performance. The idea to initiate top-down programs usually come from expert consultations undertaken by policy makers through various methods, for example Delphi, technology road mapping, technology forecasting, technology planning and benchmarking (Gallop et al. 2021; Davidson et al. 2017; Koschatzky 2009).

(Chung 2013), based on his research into innovation policy for the biotechnology sector in Taiwan, argues that top-down innovation policy for a specific technology should ideally cluster networks of involved stakeholders in order to emphasize knowledge accumulation and exploitation and encourage the production of marketable output. In addition, (Guimon & Agapitova 2013) suggest that a top-down policy for disruptive innovation is suitable for large and strategic programs that have a well-structured and experienced organization of actors and network, while at the same time those actors and networks lack resources, especially access to funding. Foster & Rana (2020), Geels (2014), Gallop et al. (2021), Hasselbalch (2017), and Jacobsson & Bergek (2004) also suggest that the suitability of policies with national context, consistency of policy, and coordination and involvement of stakeholders are the main factors for a top-down innovation policy to be successful.

Furthermore, Bush et al. (2016), through their research about top-down projects from the government in the United Kingdom which is aimed at introducing communal district heating based on renewable energy, assert that a top-down program may succeed if the government not only sets the goal, but also selects effective intermediate instruments to achieve the goal, for example networks and sub-networks of qualified actors that are able to coordinate various niche projects. Smith & Raven (2012) and Kivimaa (2014) add that beside instruments, governments need to act as leaders in order to manage those instruments to be sustainable or until they achieve the desired goals.

On the other hand, a top-down approach confronts several critics, especially when problems arise during its implementation. Disadvantages of a top-down approach is that, for example, it needs huge resources as well as skills from government in order to keep the instruments, in this case the network and its sub-networks, performing consistently (McEntaggart et al. 2020). Top-down monitoring and supervision in a big and complex hierarchical structure is also extremely costly, inefficient and has a high-risk of corruption (Ouyang et al. 2020). Moreover, the correct selection of the type of technology-priority owned by the policy may influence the private sector, for example the industry as well as consumers, to participate in the implementation of the projects (Bush et al. 2017). Bento & Fontes (2016), based on their research about system of innovation for wind power plants, argue that a top-down innovation policy that tries to introduce new innovations with a lack of compatibility and trialability with local markets may fail. Accordingly, Kountroumpis & Lafond (2018) state that disruptive technologies which have a high dependency on compatible infrastructures and require important modification to suit local conditions may be difficult to be influenced by a top-down policy.

In addition to that, Callander & Matouschek (2021) state that a top-down approach pushes governments to be smart in deciding who should act as main executor of the innovation programs related to a certain new technology. Is it better to leave a new potential innovation in the hands of strong incumbents due to their huge capacity to accelerate productivity by protecting them from competitive market? Or is it better to create competitive spaces for start-ups to grow? Boeing (2020) and Shou & Intarakumnerd (2013) argue that top-down research and innovation policy which focuses on frontier technologies, for example in China, left problematic issues due to incomplete structural reformation, such as complications in providing a competitive environment, and a lack of less-restricted entry and exit points between sectors. Thus, the implementation of a top-down policy may produce a significant negative externality. Accordingly, Pelkmans & Renda (2014) assert that state-owned enterprises which suffer low efficiency but have received political support to implement top-down projects potentially create a negative growth on productivity. The dominant state-owned company which always receives projects from the government also weakens start-ups (Pietruszkiewicz 1999).

3.4.4.2 A bottom-up approach to accelerate decentralised innovation processes

A bottom-up approach is used when the government intervenes in the projects that have already begun or have been created by actors at a grassroots level (Kountroumpis and Lafond 2018; Fan et al. 2008). In this level, the government acts as the facilitator to ease interactions between stakeholders. Furthermore, the idea of adopting a bottom-up approach in governing innovation processes starts with diagnosing the existence of actors and their interactions for a specific topic or geographical area (Chung 2013). For example, when identified innovation activities carried out through cooperation between academics or between firms or between firms and academics become the basis for the government to take action.

Bottom-up innovation programs are usually organized due to trust, common interest or complementary capabilities (Bush et al. 2016). In terms of the type of disruptive technology, a bottom-up approach is suitable for down-stream innovations that have an effect on labor intensity and provide learning opportunities for communities to use the technology (Wesche et al. 2019). The benefit of this approach for business players or innovators is the opportunity to choose the right partners to enhance their innovation activities without having the formal obligation to share their company's data or resources with the network (Brem and Wolfram 2014). In addition, this type of approach facilitates decentralized innovation processes as well as acknowledges the significance of a broad range of stakeholders outside governmental bodies by introducing a more non-hierarchical approach to govern stakeholders (Brem and Voigt 2009). Moreover, Ouyang et al. (2020) and Ristanti & Yan (2015) suggest that a bottom-up approach is beneficial in increasing the legitimacy of decentralized and participatory governance by heavily considering local activities and wisdom as they are difficult to coordinate.

A further difference to a top-down approach is that its form was defined by policy makers, e.g., through goal setting, planning, resource distribution and evaluation, a bottom-up approach lets different stakeholders organize it through a network related to the policy because their participation is mutually dependent (Maticiuc 2014). Policy makers which adopt bottom-up approaches require to know what the problem is to be solved and who are the people that should be involved in solving the problem (Gaynor 2013). Subsequently, a bottom-up approach is usually initiated with communicating the strategic idea as well as the long-term vision with potential stakeholders and recruiting them into a common innovation network or platform (Koschatzky 2009). This action is followed by the selection of project proposals which are sent by stakeholders. Through this selection, the policy maker mostly acts as resource provider and consultant to analyse the future of the novel technology and its possibility for commercialization as well as to design innovation collaborations and their impact on another relevant sectors (Möttur et al. 1978). Through the determination of involved stakeholders, the policy maker then decides the structure of the network and the position of the policy maker within the network (Bush et al. 2017). The network might either be dominated by the policy maker, or be open to have consensus among members of the network in order to freely choose their leader, or be dominated by a limited number of strong stakeholders (Huang et al. 2020b). Implementation is the next step. In this phase, the policy maker needs to ensure the process of technological innovation evolvement and stability of the network (Bittencourt et al. 2020b). The key to this phase is that there is a fair distribution of benefits among members, effective and efficient conflict resolutions and the possibility for members to engage in a long-term relationship within the network (Dhanaraj and Parkhe 2006).

One of the disadvantages of a bottom-up approach is that there is a need for policy makers to have strong capacity as well as adequate resources to change the current dominant technological regime by selecting the potential multiple stakeholders and their collaborations in order to group them in a policy related platform or interface so that they can build a new systemic innovation processes (Kivimaa 2014). Problems may occur when different actors have different claims, or when relationships among actors become unstable, thus going back to the dominant control of government (Suntharasaj 2013). In addition, members become unsatisfied when the common platform is solely used by key stakeholders to pursue their own business and neglecting the existence of the rest of the members (Numata et al. 2018). Other challenging aspects of a bottom-up approach include the emerging phase of the network. In this stage, communication among stakeholders requires a neutral and unambiguous facilitator who has has capacity to be a strong motivator for stakeholders to participate (Leydesdorff 2005). Furthermore, the network members may feel insecure as the political regime changes over time and loses its commitment because it opens up the possibility for policy makers to change their long-term core plan, to cancel their current activities or to even destroy their current achievement (Park and Kim 2020). The unfair policy makers may also disturb the performance of the network by excessively controlling the behaviour of stakeholders and by only limitedly offering short and unstable funding mechanisms to the network due to their low trust in stakeholders (Rabadjieva and Terstriep 2021).

3.4.5 Incumbent firms as the main network orchestrators

3.4.5.1 Incumbent firms and disruptive innovation

Breakthrough innovations as contradictions of incremental innovation are depicted as broader than just technological overtures because they create new know-how, materials, assets, skills and completely new entrepreneurs in the industry (Eggers and Park 2018; Engwall et al. 2021). They generate a new business environment that is contradictive with, or challenging current business belonging to incumbent firms (Andersson and Eriksson 2018b). Since most disruptive innovations are outside their speciality, incumbent firms require access to external resources through building collaborative networks related to the new innovation as well as to orchestrate it in order to avoid being thrown out of the business. To get better access to new entrants in the early development stage of breakthrough innovations is also a way for incumbent firms to make new entrants difficult in surpassing them (Aksenova 2020). Reaping external resources and taking advantage of the experience of other actors are key (Bergek et al. 2005). In addition, the network is a place for open-minded incumbent firms to carry out experiments with the new innovations by creating collaborative innovation ventures under their autonomous business unit which has a higher efficacy than an in-house research and development (Christensen and Raynor 2010; Cowden and Alhorr 2013). Continued support through sharing knowledge provides a positive impact to the experiments (D'Ippolito et al. 2019). Incumbent companies may coordinate various activities under collaborative movements in order to create a broader innovative solution, to develop diverse stakeholders in coping with policy and to control the value creation process dynamically (Andersen and Andersen 2014). If it is possible, they also need to declare themselves as the main supporters of the breakthrough innovation to secure their current business (Kammerlander et al. 2018).

3.4.5.2 Incumbent firms, disruptors and innovation ecosystems: To what extent do incumbent firms orchestrate the ecosystem of emerging innovation?

How do incumbent firms orchestrate innovation networks?

Kim et al. (2022), through their analysis of the automotive industry in east Asia, suggest that incumbent firms orchestrate ecosystems for the disruptive innovation by leading the innovation consortium to secure techno-leadership and at the same time reducing the speed of innovation. In addition, Cozzolino et al. (2021) argue that incumbent firms are aware that they need to see networks of disruptive innovation as a means to coo-perate and compete with new entrants simultaneously. To do this effectively, incumbent firms handle each step of the evolution of the network differently (Pushpananthan and Elmquist 2022; Cozzolino et al. 2021; Cozzolino and Rothaermel 2018; Jacobides et al. 2018). For more details, Table 3-4 illustrates the behaviour of incumbent firms as orchestrators of emerging innovation networks.

Table 3-4 Behaviour of incumbent firms as orchestrators of emergence innovation networks

1.Phase	**Transition to 2. Phase**	**2.Phase**	**Transition to 3. Phase**	**3.Phase**
Cooperation		**Competition**		**Coopetition**
Incumbent firms cooperate with new entrants • to learn about new technology • to gain recognition as supporter of disruptive innovation • to keep selling their remnants inventories in market using a new image meanwhile, • New entrants cooperate with incumbent firms to exploit current resource of incumbent firms to support disruptive innovation	Decreasing trust between actors within network due unfair domination and lack of transparency	Incumbent firms create collaborations among themselves in order to re-create products of new entrants for high-end market	Incumbent firms experience a lack of technical and expertise to create new value towards disruptive innovation without keeping relationship with new entrants	Cooperation between incumbent firms and new entrants as one entity to develop disruptive innovation in the industry Competition between incumbent firms and new entrants to dominate the market and maximize profit from the network

Source: Adapted and adjusted by the author from (Pushpananthan and Elmquist 2022; Cozzolino et al. 2021)

- In the early phase of the creation of networks for disruptive innovations, incumbent firms cooperate with new entrants in order to locate the ''black box'' of the disruptive innovations and complementary resources from partners through research, knowledge sharing and demonstration projects (Kim et al. 2022). At the same time, they use the platforms to declare themselves as supporters of disruptive innovations so that they can penetrate the business ecosystem of new entrants in order to be able to commercialize their current products or their remaining inventories with their new image (Pushpananthan 2022). In order to ease the access of entering into cooperation agreements with new entrants, incumbent firms may firstly optimize the function of their managerial practice, for example by deliberately forming a specific business unit for the new innovation (Chiaroni et al. 2019). Meanwhile, new entrants have several motivations in cooperating with incumbent firms. Despite their reluctance to disruptions, incumbent firms potentially support start-ups in times of uncertainty by helping them gain legitimacy, social ties and acceptability from heterogenous parties in the industry (Curwen et al. 2019). For more details, incumbent firms may become a source of breakthrough innovations due to some factors, including: 1) Large incumbent corporations usually have a strong technological capacity, especially in terms of a broader knowledge base and R&D capacity which can facilitate innovation processes (Christensen 1997; Kivimaa et al. 2021); 2) Due to the prominent status in the industry, in terms of network and lobbying capacity, strong incumbent companies have the competency to reduce barriers which arise from existing business systems as well as to force change in the industry ecosystem; 3) Big assets, a strong supply chain as well as access to a market of incumbent enterprises create possible opportunities for new entrants to cooperate in order to meet their new demands (Cirera and Maloney 2017; Brunekreeft et al. 2015; Gawer and Cusumano 2014);

- The first phase of evolvement of disruptive innovations' networks between incumbent firms and new entrants conceivably ends and enters a transition process to the next level when there is no more trust or agreeable distribution of benefit gained from the network, and this is explained either formally or non-formally by either one or both sides (Wallin et al. 2021). In this case, Diekhof (2015) argues that conflicts between incumbent firms and start-ups conceivably occur because there is an asymmetric relationship between them from the beginning. He suggests that incumbent firms usually gain more benefit than start-ups because they have established a high level of capability in order to access, assimilate and exploit know-how which appears in the networks. The situation potentially gets worse as new entrants limited their cooperation with incumbent firms or rearrange their collaborations by selecting more ideal partners (Cozzolino et al. 2021; De Groote and Backmann 2020). When this situation occurs, members enter the second phase of their networks' evolvement.

- Within the second phase, incumbent firms increase the atmosphere of competition with new entrants by creating a cooperation platform which consists of multiple incumbent firms within the networks (Changoluisa-Acuna 2014). The group of incumbent firms aims at using the networks to create a new version of the new entrants' products but with a higher quality and exclusivity so that they can control the high-end market as well as establishing a protection mechanism, such as using a patent and copyright (Alpkan and Gemici 2016).

- As the competition continues, incumbent firms enter a new level of insecurity as they face challenges in building specialized complementary assets in high-end markets alone since it is time-intensive, uncertain, ''path dependent'', and resource consuming (Wallin et al. 2021). Therefore, they need to arrange new cooperation with new entrants, especially which work at level up-stream markets with high quality innovation activities, to create new ecosystems for the new technology together (Cozzolino et al. 2021). In this situation, both new entrants and incumbent firms agree to enter the new phase of the so-called coopetition (Cozzolino et al. 2021; Ranganathan et al. 2018).

- The third phase illustrates the situation where new entrants and incumbent firms agree to conduct cooperation in term of the standardization of components or common strategy to face external barriers, for example dealing with inconducive industrial policies from the government, while at the same time competing with each other in selling their products, establishing dominance and maximizing network resource utilization (Ivarsson 2018). In this stage, cooperation between incumbent firms and start-ups stresses on several factors, including similarity of motivation and goals, cultural fit, overlap of particular technological know-how in addition to complementary and compatibility in overcoming potential risks, so that they can leverage synergies, integration and effectiveness (De Groote and Backmann 2020). In a later period, powerful incumbent firms may increase their interest in leveraging production of the new technology both in down-stream and up-stream markets by drawing their market influence and economies of scale, thus surpassing new entrants in the mature phase of technological innovation processes (Diekhof and Cantner 2017; Diekhof 2015). For example, in the case of the development of the digital music industry, Chiaroni et al. (2019) conclude that in the end, due to its power, focal incumbent firms decided to conduct the acquisition of disruptors because it was anefficient solution to lock knowledge assets and the future of the new innovations.

<u>How do incumbent firms fail new entrants or even curtail disruptive innovation networks?</u>

- Strong incumbent firms and weak intellectual property right protection

Cozzolino & Rothaermel (2018) who conduct research regarding competition between incumbent firms and new entrants in different patent regimes, suggest that a legal protection mechanism as external factor that controls innovators for gaining benefit. Furthermore, collaboration between incumbent firms and innovators might produce downsides for innovators due to knowledge misappropriation by strong incumbent firms because there is a weak intellectual property right protection (Ranganathan et al. 2018; Aggrawal and Wu 2018). In the process, possible barriers may be set by incumbent firms to overcome the innovations through using their brand (Bergek et al. 2005; Autio 2021). Incumbent firms copy the new product in the market and then sell the similar product but with a lower quality using their brands (Cozzolino et al. 2021). To overcome this, new entrants may try to survive in the business ecosystem by declaring themselves as colleagues of incumbent firms instead of competitors (D'Ippolito et al. 2019). In addition, new entrants may also simultaneously create demand from segmented markets by using a specific strategy which avoids dependency or cooperation with traditional business systems belonging to incumbent firms, for example by having different partners to deliver the products or avoiding contact with seller associations or auction houses which have connection with incumbent firms (Christensen and Raynor 2010). They try to sell the products direct to retailers or direct to exporters (Kim et al. 2022; Christensen 1997)

- Strong incumbent firms and political lobbying

Using a framework of multi-level perspectives on system of innovations, Geels (2014) states that policy makers and incumbent firms can be illustrated as a core alliance that forms the technological regime. He elaborates that at some points, they have the potential to maintain the status quo. This explanation is also supported by findings of studies done by Rechsteiner (2021), Newell (2020), Trubnikov (2017), Davidson et al. (2008), and Pelkmans and Renda (2014). Furthermore, by using the example of the energy sector, Burke & Stephens (2018), Isoaho et al. (2017), and Dallamaggiore et al. (2016) argue that policy makers deliberately support fossil-fuel industries and the other way round, thus restricting the development of renewable energy. The analytical argument based on this example is that there is a mutual dependency between incumbent firms and policy makers. Incumbent firms expect policy makers to be able to provide ''the stage and the orchestra'' for business players to play through the determination of formal and informal rules of the game for them. On the other hand, policy makers have a dependency on incumbent firms to pay tax and provide jobs (Geels 2014). Furthermore, in relation to the formation and sustainability of system of innovations, strong incumbent firms might play to sustain their domination in the market through making close contacts with prominent politicians which are in power (Gallop et al. 2021). Those contacts lead policy makers to internalize the interests of business elites so that they would have a similarity in terms of general aims, articulation of issues or problems, and determination of solutions (Burke and Stephens 2018).

3.4.6 Universities as main network orchestrators

Universities are mentioned in studies as creators of potential ecosystems for technological innovation development due to their ability to carry out interdisciplinary research and teaching activities which are aimed at providing platforms for innovators, especially young people, to spark ideas into entrepreneurship (Ugnich et al. 2017; Etzkowitz 2018). The competitive point of a university that makes it able to act as an orchestrator of an innovation network is that it is flexible and ideally impartial in facilitating interrelationships between heterogeneous end-users, innovators, firms and government (Taxt et al. 2022). It also may have a long term perspective and thirst for new knowledge (Reichert 2019). In addition, it may act as a leader in the collaborative arrangements due to its existing innovation related infrastructure, for example business incubators, science parks, and offices for intellectual property right consultations (Rissola et al. 2017).

Activities within the cooperation carried out by universities might not only be about research and teaching activities, but also the co-creation of new-innovations that covers other movements, such as investment facilitation, resource mobilization and the creation of an advocacy coalition or social legitimacy for new technologies (Khademi 2020; Huang et al. 2020c; Cai et al. 2020b). In order to pursue the goal, the complex network composed of individuals, departments, units, and programs is suggested (Spiegel et al. 2016). Furthermore, geographical factors or spatial closeness between university, industry and society might influence the role of the university in executing its potential in creating linkages with interorganizational-collaborative innovation activities (Leon and Martínez 2016). Nevertheless, in order to not go beyond its specialty as academician, universites consider three activities as their main job: supervising through educational offers and exploitation of research outputs, providing ecosystems, e.g., incubators and science parks, for niches and allowing start-ups competition within the ecosystem (Levchenko et al. 2018). Even though studies about university-based entrepreneurship may focus on macro indicators, for example external macroeconomic-social conditions as well as a university's capacity in providing formal curriculum, scholars try to analyse the contribution of universities by stressing to what extent they develop and scale up their collaborative-innovation arrangements into real business opportunities. For example, Xie & Zhang (2019) suggest that there are several factors needed to be looked at when analysing a university's competency in orchestrating innovation processes, including the heterogeneity of actors, type of cooperation, style of interaction among actors, and vision and potentials of networks to evolve into a bigger system.

Accordingly, Thomas et al. (2021) and Del Álvarez-Castañón & Palacios-Bustamante (2021), based on their case study of a group of universities in orchestrating regional movements in south America, show that universities have the potential to create ecosystems when there are top-down policy and bottom-up initiatives that are being acted out simultaneously. As an illustration, they describe that in order to wake-up academics to be active in introducing new innovations, policy makers need to provide a specific initiative, for example a local innovation platform or funding opportunities. To react to this, universities and their potential partners from industry or group of consumers may conduct information sharing or consolidation to create alliances in order to carry out innovation activities. By acting as collaborative-network orchestrator, the universities scan their partners and define the focal figure or ambassador of the network to motivate other potential stakeholders to join in a collaborative venue that is in line with the existing top-down policy.

On the other hand, Heaton et al. (2019) explain that universities may create setbacks as leaders of an innovation movement due to the gap in communication with both communities and industry which later leads to a lack of interest in investing in the university's entrepreneur facilities. Mao et al. (2020),Ferguson & Fernandez (2015), and Drucker & Goldstein (2007) also mention that a lack of internal competency and culture of technological innovation entrepreneurship, passiveness in creating projects and teams to collaborate with external partners may contribute in hindering universities in creating innovation ecosystems. Furthermore, the ''dark side'' of universities in orchestrating innovation processes are also described in studies done by Bittencourt et al. (2020a), Reichert (2019), Xie & Zhang (2019), and Drucker & Goldstein (2007). Their findings suggest that without having specific competency towards the new technology, universities can only intervene in the network as a facilitator that can only act as organizer of meetings between start-ups, workshops, and seminars without having any power to shape the development of the network. Most of the activities would be dominated through interaction between industry, consumers and the policy makers which may decrease the significancy of the university in the innovation network (Mao et al. 2020).

Meanwhile, Taxt et al. (2022) and Rantala & Ukko (2018) assert the strength and sustainable nexus of knowledge exchange within a specific geographical area or industry allows novel innovations and up-dated knowledge to be easily communicated through mutual direct contacts. Related to this, long-established research units or academic institutions which are experts in specific types of technology as well as having strong innovation linkages in the nexus are usually able to be spontaneous and faster in accessing and sharing new knowledge with multiple actors without requiring mobilization of tremendous additional resources and time (Zhao and Hu 2021). On the other hand, universities have the potential to enter and work as representatives of global or national linkages that deliberately work to develop and intensify interrelationships among local actors in order to spread disruptive technology (Albuquerque et al. 2011). However, this may take time and is challenging for universities to persuade local actors to join the platform without having several competencies, for example: certified knowledge related to the disruptive technology, the capacity to facilitate funding or mobilize new investment, having contact with prominent business players of current technological regimes, providing a compatible infrastructure to explore and develop the new technology, and having a positive reputation in society (Taxt et al. 2022; Del Álvarez-Castañón and Palacios-Bustamante 2021; Cohen 2016).

3.5 Performance of innovation networks in implementing functions of TIS

3.5.1 Collective and non-collective actions in networks to perform the functions of technological Innovation Systems (TIS)

The use of the concept of innovation networks in technological transitions literature as a specific unit of analysis for describing the functions of a technological innovation system (TIS), is somehow still partial and implicit (Herstatt and Lettl 2004; Bleda and Del Río 2013; Blum 2013; Jansma et al. 2018; Bergek et al. 2008c; Kao et al. 2019). Meanwhile, Gosens & Lu (2013) and Quitzow (2015) assert that networks can be seen as essential perspective in order to see the functionality of a TIS not only from general indicators, e.g.number of patents, gross national income and foreign direct investment, but also in terms of various interrelated as well as overlapping actions of actors. A more detail illustration, in order to answer who performs those functions and how those functions are performed, is also a potential outcome of the analysis of system of innovation using network context (Schön and Pyka 2012; Karltorp 2014). Hekkert et al. (2007) and Bergek et al. (2008a) add that by understanding the activities that fulfil TIS functions, further analysis to understand specific activities that can be either the potential motor or barrier of the system formation of a TIS, can be carried out.

Furthermore, Musiolik (2012), and Musiolik & Markard (2011) assert that it is important to identify whether activities related to TIS functions are carried out collectively or individually in order to measure unity between stakeholders as well as to see an indication of the domination of TIS functions' fulfilment by a limited number of actors. According to Loorbach & Van Raak (2006), if a certain actor could control or imprint the network due to its single action, then the actor will potentially be at a strategic level or be leader of the network. They add that collective innovation movements usually illustrate the tactical and operational domain of involved stakeholders. For more details, Table 3-5 depicts the organization of activities within innovation networks in order to perform TIS functions. It shows that most TIS functions require interaction between actors, and thus are mostly carried out collectively. Those include the implementation of demonstration projects, R&D projects, knowledge sharing and creation of legitimacy (Hekkert et al. 2007; Hellsmark et al. 2016).

Table 3-5 Collective and autonomous implementation of TIS functions within innovation networks

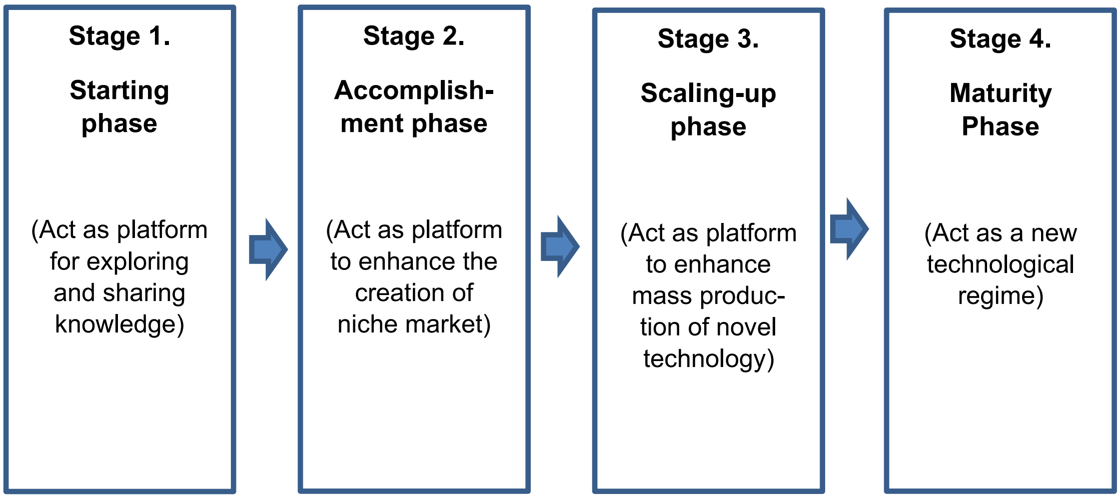
Type of TIS functions	How network covers TIS functions		
	Implemented collectively through co-operation arrangements	Implemented or issued only by a limited number of specific actors, e.g., policy makers	Implemented autonomously by single actor e.g., focal firm/incumbent firm , new entrant or university
F1 On-site demonstration projects /technology incubation and niche market creation	√		
F2 Research and Development project	√	√	√
F3 Knowledge sharing	√		
F4 National-formal Program/Vision/Technology standardization		√	
F5 Fiscal measures to enhance technology utilization or market formation		√	
F6 Investment/Funding	√	√	√
F7 Creation of legitimacy through classes, campaigns and lobbyings to increase recognition or awareness of society as well as advocacy of movements related to new innovation	√		√

Sources: Adapted and adjusted by the author from (Hellsmark et al. 2016; Bento and Fontes 2015a; Bergek et al. 2008a; Binz et al. 2014; Hekkert et al. 2007)

- Demonstration projects aim to create or develop sellable innovation (Anadon et al. 2016). At the beginning, it should be innovators who can directly test their product in a limited number or limited area of consumers (Caniels and Romijn 2006; Raven et al. 2011). Networks allow this activity through collaborative arrangements, for example, through cooperation between new-entrants and incumbent firms; or new-entrants with universities; or new-entrants and end-users using the help of policy makers (Schilpzand et al. 2010; Schot and Geels 2008).
- Knowledge development is the soul of innovation and can be found out through collective and individual movements (Bergek et al. 2008b; Esmailzadeh et al. 2020).
- Knowledge sharing reflects the circulation of information between different members of innovation platforms; therefore, this activity should be collaborative (Jansma et al. 2018; Jain et al. 2017).
- Only a limited number of parties can have the power to influence the common direction of the innovation processs, for example in the form of vision, planning or the outlook of consumers' interest (Binz et al. 2014). This can be done by government or powerful firms (Musiolik 2012).
- Fiscal measures that aim to create markets can be done by policy makers through fiscal measures to nurture niche markets; for example, subsidies, and tax (van Lancker et al. 2016; Bittencourt et al. 2021).
- In order to mobilize resources, especially financial assets in terms of new investment, innovation networks may provide possibilities to facilitate those activities, for example by enhancing collaboration between banks, governments, and firms (Tigabu et al. 2015b). In addition, investment to develop new innovation can also be undertaken autonomously by each stakeholder within the network (Gosens and Lu 2013).
- Creation of legitimacy can be done through various ways, including political debate, and campaigning the importance of novel innovation in mass-media or in schools (Bento and Wilson 2014; Hekkert et al. 2007). It could be done either individually, for example by a university or a prominent industry player, or through collective actions within a specific innovation ecosystem. The goal of the activity is to gain social recoqnition as well as type of manoeuvre to attract policy makers to participate in innovation processes (Bergek et al. 2008c; Binz et al. 2014).

3.5.2 Macro-level illustration of the evolution of innovation networks through their aggregate performance to cover TIS functions

Performance of innovation networks in fullfing TIS functions can indicate the level of evolvement of networks to grow into a system in general. Regarding this, Bento & Wilson (2014), Pushpananthan (2022), Changoluisa & Fritsch (2014) and Suurs (2009) suggest that innovation networks grow through four different phases in order to be able to handle systemic innovation processes. They argue that those phases include the starting phase, the accomplishment phase, the up-scaling phase and the growth or maturity phase (See Figure 3-2).



Source: Adapted and adjusted by the author from (Bento and Wilson 2016, 2014; Pushpananthan 2022; Changoluisa and Fritsch 2014; Suurs 2009)

Figure 3-2 Development of innovation networks in operating TIS based on general performance of their elements

- In the first phase of system of innovation emergence, innovation networks are mostly less formal and focus on innovation development and sharing information. The formation of collaborative projects or process of actors to have a will to join the network is rather slow. Innovation movements, such as R&D activities, knowledge sharing and lobbying, mostly concentrated to those actors that come from less heteregounous backgrounds, mainly from universities or innovators. Appearance of technology in this stage is still in the form of various ideas and definitions (Bergek et al. 2005). Governments may contribute to facilitate funding and issue national visions or programs for scientific activities related to new innovations (Binz et al. 2014; Bergek et al. 2008b; Blum 2013).

- The second phase of network evolvement illustrates innovation networks that develop slowly from a starting point as a mere platform for knowledge circulation into being capable of actualising results from scientific activities in the form of entrepreneurial experimentations because there is already the achievement of innovators in providing selection of first prototypes with different possible designs (Bento and Fontes 2015b; Bergek et al. 2005). In this situation, networks aim to optimize their performance in creating strong information exchanges between innovators, end-users and R&D executors through demonstration projects and the creation of niche market (Geels 2002). The second stage of innovation networks' emergence depicts more temporary linkages between business and public organizations with the possibility of success and failure of actors in introducing new innovation into a limited segment of potential users (Brenneche 2013; Markard et al. 2015; Bento and Wilson 2014).

- The third phase is called the up-scaling stage because the networks grow into being more stable by having more hetergenous actors who work together and are capable of scaling-up the initial market (Markard 2020). In this phase, more activities to mobilize capital and advertise new products in society is very significant (Suurs 2009). In addition, in the third phase, governments may start to be more attentive by providing a specific fiscal measure as well as a technical -related policy, e.g. anational technology standard to influence the growing market (Wang and Wang 2016; Esmailzadeh et al. 2020; Hellsmark et al. 2016).

- The mature stage of innovation networks is characterized by the success of a new technology to be acknowledged as a new regime due to its achievement in delivering it into society as a mass product (Bergek et al. 2010; Suurs et al. 2010; Hekkert et al. 2007). In this context, a complex innovation network with a large number of actors from different backgrounds is seen as an established industrial network (Suurs and Roelofs 2014; Ortt and Kamp 2022). The significant TIS function in this level is to generate equilibrium between consumption and production that may be influenced by fiscal policy and non-fiscal policy (Planko et al. 2017; Markard 2020; Mignon and Bergek 2016).

3.5.3 Micro-level illustration of the evolution of innovation networks through the development of entrepreneurial experimentations

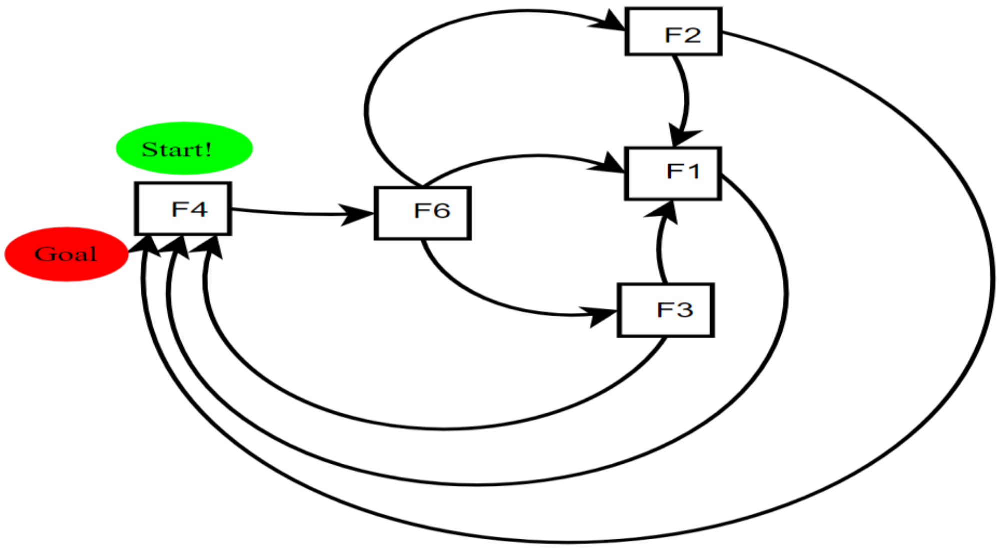
A more limited scope of analysis about changes of niche technology into widely marketable products through entrepreneurial experimentations also plays an important role as an illustration of innovation processes that take place at a micro-level (Hekkert et al. 2007). Related to this, Bleda & Del Río (2013) state that entrepreneurial experimentations are the core activities in TIS because they are a link between the knowledge network and the market network. They also elaborate that those entrepreneurial experimentations aim to create markets and may begin in the form of demonstration projects.

According to Lefevre (1984), Loorbach & Van Raak (2006) and Suurs & Roelofs (2014),demonstration projects are shortcut activities in order to make new technology widespread and acknowledged. They argue that demonstration projects aim to test the functionality of a new technology, to estimate the cost and risk as basic information for potential investors when they want to expand the process, to re-create the new technology to be suitable into local conditions, to identify aprimary audience, e.g., especially from policy makers, potential early adopter, technical experts, to recognise significant stakeholders that are against the new technology, and to analyse possible political support that is significantly needed to expand those activities. Furthermore, Macey & Brown (1990) distinguish demonstration projects into two classifications: ‘’experimental’’ and ‘’exemplary’’. Experimental demonstration projects aim to assess the suitability and performance of a certain new technology in a particular condition and communicate it to opinion leaders or potential early adopters, whereas exemplary demonstration projects have the goal to commercialize new innovation that may have been reconfigured to follow different local conditions. Usually, experimental comes first before exemplary (Wesche et al. 2019). In this stage, governments may act as one of opinion leaders in industrial ecosystem in order to influence those activities by issuing agendas or programs that have a correlation with the new technology (Bleda and Del Río 2013).

Meanwhile, Loorbach & Van Raak (2006) use the term of niche experimentation in order to describe the process of entrepreneurial activities within innovation networks. According to them, niche experimentations depict the evolution process of novel technology and institutional frameworks in order to be compatible and create its distinguished economic success. In addition, Anadon et al. (2016) assert that niche experimentations allow innovators to conduct trial and error under protected environments as well as to collect feedback due to the introduction of new innovations to early users. They also argue that activities within project levels may very slowly cause any transition in regime level, for example if ‘’technology lock-in’’ created by powerful incumbent firms or political regimes exists. In addition to that, niche experimentations have several levels in order to create a new market. They are including technological niche or niche creation, market niche or niche maintenance, and mass-market or mature-stage (Boon et al. 2014; Hoogma 2000; Bush et al. 2017).

3.5.3.1 Technological niche (First level)

Technological niche is result of follow-up laboratory experimentations that are then tested in an actual situation (Bleda and Del Río 2013). If the test is a success, the first outcome is that there will be a multiplication of tests in several places. There would also be information sharing between test-projects that is very useful to optimize product development (Gliedt et al. 2018). The time frame to conduct the project for testing the novel technology is not always long, it depends on the result of interactions between the novel technology and early users and also the capacity of innovators in supplying it. Positive results of the test usually leads to a market niche (Binz et al. 2014). According to Seyfang et al. (2014), a technological niche is usually seen by opinion leaders, e.g. incumbent firms and government, as low-profile activities to create pre-marketable products because it is mostly carried out by intensifying the interaction among a limited number of homogenous actors. In this case either innovators or universities. They add that opinion leaders, nevertheless, have sort of expectations that the new innovation could be either solutions of an actual problem in society or offer significant economic benefit.



Note:

F4: Innovation Program from government;

F2: Research & development projects;

F1: Demonstration projects

F6: Funding from government

F3: Knowledge sharing activities

Source: Adapted and adjusted by the author from (Gosens and Lu 2013; Suurs 2009; Suurs and Hekkert 2009)

Figure 3-3 Knowledge motor

In addition, Suurs (2009) and Gosens & Lu (2013) argue that in the early phase of entrepreneurial experimentations of new technology, the aim of actors is to make on-site pilot projects continuous and successful. In order to do so, they conduct their activities with the availability of programs, specifically funding opportunities, and aim for next and sustainable programs. Related to this, Suurs & Hekkert (2009) assert that, given time, where a new idea to create an innovative and problem-solving technology is coming to a new territory, the policy makers could act as a significant actor to influence the process for being a creator of an innovation's motor or programs provider.

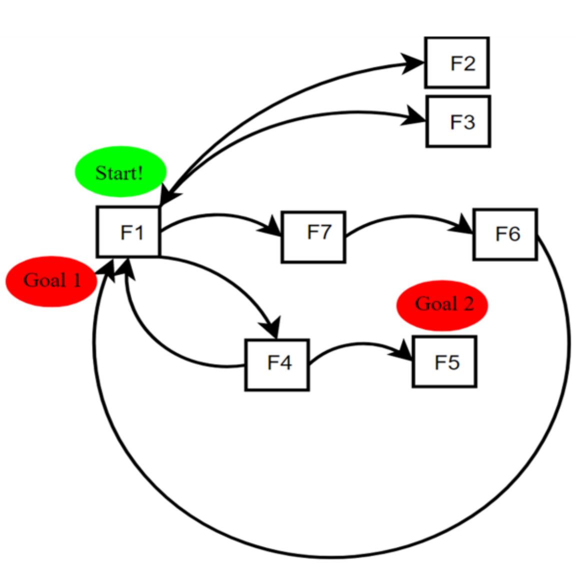
Furthermore, Figure 3-3 illustrates a knowledge motor with government as the innovation motor's creator by providing stakeholders the opportunity of being in the phase of niche creation. The goal of the motor is to provide a more sustainable program that might enhance innovation processes. The starting point of innovation movements is through innovation policy or program for a specific technology (F4) that is then followed by funding opportunities (F6) or investment schemes for R&D projects (F2), knowledge sharing activities (F3) and demonstration projects (F1) that are usually implemented by universities and innovators (Pesch et al. 2017). They add that in this stage, R&D projects (F2) and information sharing between actors (F3) usually contribute significantly to the implementation of demonstration projects (F1). Demonstration projects in the phase of niche creation are mostly decentralized and dominated by universities or innovators and concentrate on the exploration of new knowledge (Suurs et al. 2010). As for universities, they implemented this phase in order to study a novel technology that may have come from abroad (Egbetokun et al. 2017). Once those projects sucessfully provide positive outcomes, it is possible for policy makers to provide reactions in term of changes on its policy to give a second round of support to the innovation movements, and vice versa (Suurs 2009). The general impact of the creation of an innovation's motor by the government include the opportunity for different stakeholders to share their vision and build networks to enhance the innovation (Bento and Fontes 2015a). Nevertheless, Suurs (2009) argues that as a controller of an innovation's motor, policy makers may have preference to maintain the status quo and indeed deploy an inconducive policy that creates a barrier to the movements.

At the level of implementation, the motor usually requires several conditions to function, for example strong universities and industry, in terms of knowledge capacity and network, capability of policy makers, especially in terms of resources, and feasibility of new technology (Möttur et al. 1978; Bittencourt et al. 2021; Bittencourt et al. 2020a). Specifically, for executors of demonstration projects, they may experience difficulties and need to cancel their projects due to a shortage of skills, continuous problems in fixing failures, not actively articulating or circulating their experience with other related projects, and failing to sound their projects in a broader audience due to less consolidation due as a result of the high cost of communication or significant geographical distance (Seyfang et al. 2014; Hargreaves et al. 2013; Egbetokun et al. 2017).

3.5.3.2 Market niche (Second level)

In this stage, technology is developed to be compatible with the preferences and culture of users and the macro-economic-environmental situation (Changoluisa-Acuna 2014; Changoluisa and Fritsch 2014). In other words, it is time to make novel technology, which is already marketable, part of the life of society or to be able to generate a new regime in the industry (Schot and Geels 2008). Policy makers or incumbent firms may start to pay attention because of the availability of the new technology that offers market potentials. They usually start to have interest to invest in the production of the new technology or deploy fiscal incentives (Smith and Raven 2012). Furthermore, market niche brings about a struggle for gaining support, especially political support, in order to be able to provide a sort of market protection to the novel market technology (Caniels and Romijn 2006). In order to do this, niche entrepreneurs strongly need to gain attention from policy makers by promoting their project, to create a coalition among niche entrepreneurs to align the common concept and strategy and to maintain contact with prominent industrial or political figures about problems and solutions that lead the translation of it into a political agenda (Pesch et al. 2017).

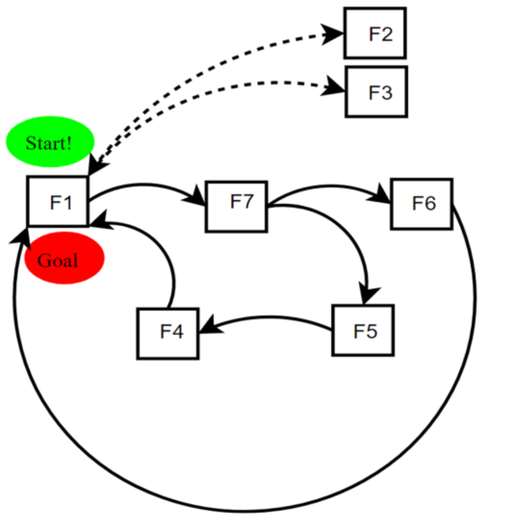
Moreover, according to Caniels & Romijn (2008), Caniels et al. (2007), and Suurs & Hekkert (2009), in the market niche phase, innovators or new entrant firms are the main actor who needs to build their own innovation's motor. They are two different innovation motors in times of niche maintenance and scale-up; namely ''entrepreneurial motor'' and ''system building motor''. ''Entrepreneurial motor'', or new business motor, aims to increase investment as well as to create protective space for new technology, whereas ''system building motor'', or systemic business motor, focuses on creating a new technologicial regime through a significant and sustainable amount of production of new technology with less financial protection but more concern for consumers' safety (Powell et al. 1996; Jansma et al. 2018; Suurs 2009). Furthermore, Figure 3-4 illustrates two types of innovation motors that are developed by new entrepreneurs. Fig. A depicts new business motor, whereas Fig. B illustrates systemic business motor.



A. New Business Motor

Note:
F1: niche maintainance/scaling-up market;
F2: Research & development projects;
F3: Knowledge sharing activities;
F7: Lobbying between new entrant firms and incumbents/banks;
F6: Investment;
F4:Recognition from government;
F5:Possibility of fiscal policy to enhance niche market

Source: Adapted and adjusted by the author from (Caniels et al. 2007; Changoluisa and Fritsch 2014; Suurs 2009; Suurs et al. 2010)



B. Systemic Business Motor

Note:

F1: mass production;
F2: Research & development projects;
F3: Knowledge sharing activities;
F5:Deployment of fiscal policy to enhance niche market;
F6: Investment;
F4: Government policy may includes industrial competition, standardization and consumers' protection
F7: Lobbying between entrant firms and incumbents/banks, lobbying between firms and politicians

Source: Adapted and adjusted by the author from (Caniels and Romijn 2008; Pesch et al. 2017; Smith and Raven 2012; Suurs 2009; Suurs and Hekkert 2009)

Figure 3-4 New business motor and systemic business motor

New business motor

In Figure 3-4-A, it is shown that new entrant firms carry out continuous activities to develop samples of new technology (F1) into suitable products for the current market and thus can gain more economic benefit (Boon et al. 2014). Through utilising the new business motor strategy, innovation processes through R&D activities (F2) and knowledge sharing (F3) are conducted not only by universities, but also by firms and a limited group of citizens which have interest in the new technology (Suurs et al. 2010). In addition, there is a mutual relationship between F1, F2 and F3 (Gosens and Lu 2013). Within activities of F1, entrepreneurs rely on particular external actors, especially new adopters, to initiate and conduct learning processes due to their knowledge and past experiences in dealing with the new products (Seyfang and Haxeltine 2012; Hargreaves et al. 2013). In addition, F1 might does not develop when actors in niche projects only have a limited platform to share their experience to a limited number of groups of entrepreneurs or potential investors (Seyfang et al. 2014).

Furthermore, using this motor, new entrepreneurs might be able to conduct lobbying (F7) with incumbent firms to create co-operation or with financial entities to get more capital injection so that they can scale-up their product development as well as their market penetration (Gosens et al. 2013). As their market tends to grow, governments may react to it by providing recognition, for example by mentioning it as an important innovation to help society, or introducing a specific non-fiscal measure, for example programs related to green technologies (F4) (Gosens and Lu 2013; Tigabu et al. 2015b). As the market keeps growing, governments may plan to provide support by introducing fiscal incentives, especially for consumers or a specific treatment to protect the infant business (F5) (Suurs 2009). In this level, the plan for F5 is not necessary to be actualized in a short-term period and may still be uncertain because of new entrepreneurs that still have limitations in term of their business scale, still do not have a strong coalition with prominent industry players and are short in their access to politicians (Choe and Ji 2019; Musiolik and Markard 2011).

Nevertheless, the general impact of a successful new business motor is that different actors in innovation processes, especially between new entrant firms and incumbent firms, have the potential to strengthen their network (Caniels and Romijn 2006; Raven et al. 2011). In several cases, the motor may not function due to various new entrepreneurs that have difficulty in generating a common vision as well as resistance from the policy makers and incumbent firms to support the new technology (Hellsmark et al. 2016).

Systemic business motor

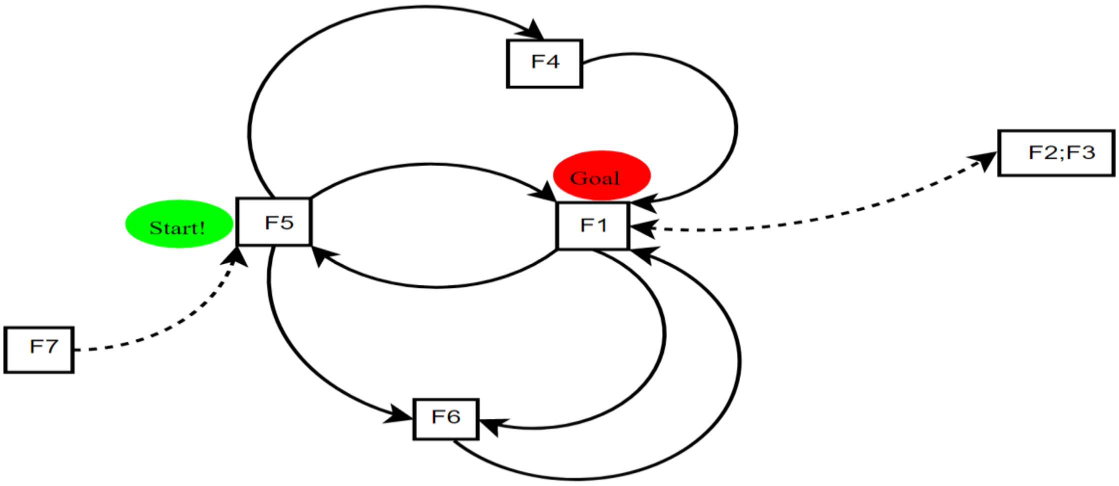
Figure 3-4-B describes innovation's motor built by new entrepreneurs that is called as systemic business motor. The motor works to generate a new business ecosystem due to the success of new entrepreneurs in expanding the market of new technology after their success in creating and running their new business motor (Suurs and Hekkert 2009; Suurs 2009). In addition, the systemic business motor requires new entrant firms to keep expanding their current up-scaled niche market (F1) (Boon et al. 2014).

In this motor, actors from a specific niche project may conduct active learning through direct experiences while running the project, this includes re-creating the innovation, testing its functionality, and dealing with failures (Seyfang et al. 2014). To optimize their result, they develop a communication platform and programs for sharing experiences with other communities and are actively engaged in articulating their lessons learnt and experiences, as well as communicating it with actors from outside collaboration platform (Schilpzand et al. 2010). In some cases, due to their success, they even act as intermediaries to many other groups outside their main network (Kivimaa et al. 2019). In addition, by using their existing contacts with financial entities, incumbent firms or large enterprises or prominent politicians, they are able to do lobbying (F7) (Musiolik and Markard 2011). The lobbying itself is carried out in order to draw more investment (F6) as well as to gain political support in terms of a protective environment for their business, especially in term of fiscal measures (F5) (Mignon and Bergek 2016). When the government starts to deploy fiscal measures, for example feed-in tariffs or tax reduction for consumers, it is possible that it might continue to work by providing further reaction through various programs or policies or infrastructure development (F4), for example by issuing product standardization, competition policy, or consumers' protection (Kebede and Mitsufuji 2017).

The motor usually creates successful outcomes when the entrepreneurs have a strong network to engage lobbying or experience a sort of ''political momentum'' to gain support in order to shift the actual technology regime (Ortt and Kamp 2022). In addition, the motor might experience a condition, where the behaviour of the end-user through using the new technology is more important to the consideration of developing the product (Caniels and Romijn 2006). Furthermore, activities such as R&D (F2) and knowledge sharing (F3) in the form of scientific activities are somehow important, but the intensity to influence the market expansion (F1) is less (Suurs 2009).

3.5.3.3 Mature stage (Third level)

When new technology is already successfully mass-marketed, innovation networks focus on maintaining the market as well as breaking down its protection (Caniels and Romijn 2008). New technology in this stage is the result of dynamic interactive learning between actors in a market, as well as adaptation to society and the political situation, in which it can accept the technology (Hargreaves et al. 2013). In this stage, entrepreneurs may run their innovation's motor, the so called ''market motor'' (See Figure 3-5). The aim of the motor is to have a balanced position between production and consumption of new technology (F1) and industrial policy (F5), especially fiscal policy, related to the new technology (Suurs 2009). In the motor, the novel technology can be easily accessed and utilized by consumers (Jain et al. 2017). Activities of R&D (F2) and knowledge sharing (F3) have less direct correlation with F1 (Caniels et al. 2007). On the other hand, government, through F5, may proceed to make changes to its policy by either slowly or rapidly eliminating the fiscal measures that leads to changes to non-fiscal policy (F4) and adjustments in investment conditions related to the novel technology (F6) (Boon et al. 2014; Hoogma 2000). In addition, since the novel technology is already becoming a part of society in everyday life, advocacy for the novel technology (F7) becomes less, except there is an accidental situation that strongly encourages business players to do lobbying in order to revise the fiscal policy related to the novel technology (F5), for example natural disasters and political turmoil that influence economic situation badly (Ortt and Kamp 2022).



Note:
F1: market;
F2: Research & development projects;
F3: Knowledge sharing activities;
F4: Government policy may includes industrial competition, standardization and consumers' protection
F5:Fiscal policy to inlfuence market;
F6: Investment;
F7: Lobbying between firms and politicians

Source: Adapted and adjusted by the author from (Markard 2020; Mignon and Bergek 2016; Planko et al. 2017; Suurs 2009; Suurs and Roelofs 2014)

Figure 3-5 Market motor

3.6 Creation of system of innovations in the context of developing countries through collaborative movements: the case of smart grid movements in Indonesia and its neighbouring countries

3.6.1 Definition of smart grid

Smart grids provide advantageous solutions because they enhance two-way flows of both electricity and information so that it becomes a revolution in the domain of generation, transmission and the distribution of electricity (Demertzis et al. 2021; El-hawary 2014; Giles et al. 2010). The basic aim of smart grids is to utilize information and communication technology in order to collect and share information in a computerized or programed fashion which aims at improving efficiency, reliability, sustainability and affordability of power system (Bari et al. 2014; Chawla et al. 2018).

In addition to that, it helps in the penetration of renewable energy resources into the grid system as well as easing the management of integration of various small and distributed power generations (Hillberg et al. 2019; Eller and Gauntlett 2017). Smart grids may decrease the dominant role of the utility in owning and controlling the operation of the electricity sector because it enhances decentralized operation and ownership of power generations (Morteza and Mohsen 2013; Kappagantu and Daniel 2018). Traditional one-way communication in the sector, in which the utility provides all and consumers just receive and pay without interval measurement but only through the calculation of accumulated usage in a certain period of time, is also possibly erased by smart grids (Goldman and Levy 2011; El-hawary 2014). In addition, the price of electricity is actionable in an energy market due to the digitalization of the power system (Joo 2019). This replaces the situation of power markets in some countries, where the utility has the only authority to set the rate of price (Bigerna et al. 2015). Furthermore, Table 3-6 presents several descriptions about smart grids according to (International Electrotechnical Commission (IEC) 2009; European Union (EU) 2012; International Energy Agency (IEA) 2011; India Smart Grid Forum (ISGF) 2017) :

Table 3-6 Description of smart grids according to different sources

Sources	Description of smart grids
(International Electrotechnical Commission (IEC) 2009)	• Smart grids are about to smarten or modernize the power system. They consist of the construction of a digital electricity network that is supported by other related modern technologies in order to supervise and manage the flow of electricity. Smart grids make the grid become ''adjustable, and capable of offering real time responses as well as reciprocal communication between stakeholders''. • Smart grids have various innovative technologies that basically propose possibilities to deploy applications for ''intelligent monitoring, control, communication, and self-healing ability'', smart networking and organizing different types of power generators, real-time access to information about energy consumption and ''choices of supply'' for consumers, and applications that enhance the level of reliability and efficiency of grid.
(European Union (EU) 2012)	• Smart grids are ''energy networks'' that offer automatic or real-time control of energy flow so that changes in demand can be optimally followed by changes in supply. • Real-time information access about energy consumption is also a part of a smart grid through the application of smart metering systems. • It also enhances the integration of renewable energy into the power system through an application that is able to provide weather forecast and incoming energy demand so that the grid operators or hybrid power plant managers can optimize the composition of various renewable energy resources as well as balance the network. • Smart grids also create more possibilities for prosumers to be active in electricity market.
(International Energy Agency (IEA) 2011)	• Smart grids provide power systems with various choices of technology that have the possibility to be deployed in different situations around the globe by reconfiguring them according to the local compatibility of technology, policy framework and economic situation. • Smart grid technologies refer to innovations that are not just to improve reliability, ecological-friendliness, and security of energy supply, but also create potential of some kind of revolutions in electricity industry, for example through enabling more participations of consumers through transparency information from energy suppliers, accommodation of various alternative energy resources and storage technologies into current electricity infrastructure, and chances for stakeholders to create new business model. In this level, societal conditions, regulatory conditions, economic situations and dynamic evolvement of smart grid technologies are major points to create the modernization or revolution in the power system.

(India Smart Grid Forum (ISGF) 2017)	• Smart grids erase boundaries between generation, transmission and distribution because smart grids evolve the power system to be integrated so that power flow can be more interactive, cost-minimized, and environmental-friendly. • Revolution in terms of the creation of new business models is also possible, for example through increasing the application of smart meter for prosumers or specific agents to manage or aggregate various small scale distributed power generations.

Source: Author's compilation

In addition, smart grids consist of software and hardware solutions for different purposes. Those innovations, however, usually require particular basic complementary conditions in order to be able to be utilized. For more details, Table 3-7 shows examples of smart grid technologies for different purposes.

Table 3-7 Example of smart grid technologies

Domain	**Hardware**	**Software**	**complementary condition**
Network and asset management	-	Wide Area Monitoring Systems (WAMS), Wide Area Protection and Control (WAPC), substation automation, distribution grid monitoring and management, outage management systems, self-healing/fault locator systems, advanced asset management, data communication system	Favourable regulatory framework, standardization, compatible infrastructure
Demand side and customer management	Advanced Metering Infrastructure (AMI), smart-meters, in-home displays, servers, relays	Meter data management system (MDMS) Automatic Meter Reading (AMR), Energy Management Systems (EMS), Customer Relation Management (CRM), Time of Use-tariffs (ToU) and real-time pricing, Demand Response (DR), Demand Side Management (DSM)	Favourable regulatory framework, standardization, available of stable internet connection
Integration of distributed generation and storage	Virtual power plant (VPP), microgrid, communication and control hardware for	Distribution Management System (DMS), Supervisory Control and Data Acquisition System (SCADA),	Significant share of renewable energy on the grid, favourable regulatory

	generation and enabling storage technology, network planning and analysist tools	Geographic Information System (GIS), forecasting system	framework, compatible infrastructure
Integration of renewable and storage bulk power	High Voltage Direct Current (HVDC) transmission, Dynamic Line Ratings (DLR)	Flexible AC Transmission Systems (FACTS)	favourable regulatory framework, compatible infrastructure
Electric mobility	Charging infrastructure, batteries, inverters	Energy billing, smart charging Grid to Vehicle (G2V), discharging Vehicle to Grid (V2G) methodologies	favourable regulatory framework, compatible infrastructure

Source: (Elzinga 2016; Komor et al. 2013; Kappagantu and Daniel 2018)

3.6.2 Developing countries and the goal of their collaborative innovation movements for renewable energy technologies

According to Rihan et al. (2011) and Lin et al. (2013), the development of the renewable energy sector in developing countries depicts different situations because each country may have its own priority and capacity in implementing the innovation processes of renewable energy technologies. Nevertheless, during the process, in general, the intervention of policy makers in each step or process when dealing with renewable energy technologies is very crucial in developing countries due to a lack of capacity of entrepreneurs and households/end-users, especially in terms of financial and technological knowledge (Borup et al. 2013). Subsequently, a developing nation may either prioritize its state-owned companies or government related bodies to develop its own renewable energy sector, or focuses on just being in the market for green technologies where the main technologies are from abroad, or in between (Huang et al. 2016; Lin et al. 2013; Autant-Bernard et al. 2010; Feng 2016). For more details, based on their objectives in handling renewable energy sector, developing countries can be categorized into three groups, including global technology supplier, technology user and local technology entrepreneur (See Table 3-8).

Table 3-8 Different categories of developing countries based on their objectives in developing renewable energy sector

Category	**Aim**	**Attention receivers**	**Possible focal actors in creating collaborative innovation linkages**
International technology supplier	To produce its own technology initiated by government and sell it to international markets	State owned companies and their affiliation	State owned companies/government related bodies
Technology user	To create local markets	End-users	Government bodies, public universities, state-owned utility, group of private early adopters, international agents (innovators or NGOs)
National entrepreneur	To create local markets but prioritizing local suppliers	State owned companies/government related bodies and local end-users	State owned companies/government related bodies, public universities, group of private early adopters, group of local innovators

Source: Elaborated by the Author based on (Huang et al. 2016; Lin et al. 2013; Autant-Bernard et al. 2010; Feng 2016)

An emerging nation that aims to be a global technology supplier of green technologies usually focuses on enhancing learning activities in different government related bodies, for example state owned companies, public universities and research centres, by giving them access to create links with the private sector, especially from international counterparts (Feng 2016). Through this, knowledge exploration, experimentations and modification of novel technology can be carried out between educational and industrial domains (Huang et al. 2016). Furthermore, this nation usually deploys its fiscal policies for its object priorities, especially for generating products, technology incubations, access to export markets through tax or investment opportunities and investment in R&D activities (Autant-Bernard et al. 2010). In this case, China is mentioned in several studies as a country that belongs to this category (Huang et al. 2016; Feng 2016; Gosens and Lu 2013).

Meanwhile, developing countries that act primarily as market or receiver of any innovation of renewable energy technologies usually have the starting point from acquisition of any new technology done by government related bodies (Kebede et al. 2015). In other words, in order to create demand, government acts as early adopter of the novel technology through public procurement. In addition, policy makers might give facilitation to government related organizations, for example, public research institutes or universities, to explore and multiply the adoption of the technology (Tigabu et al. 2015b). During this process, governments usually apply financial subsidies to early adopters, for example, in terms of a feed-in tariff (Lawson-Lartego and Mathiassen 2016). The priority is also on the process of technology transfer that occurs between foreign agents and local actors (Siegel and Strong 2011; Vidican et al. 2010). Kebede & Mitsufuji (2017), Mohammadi et al. (2013), Tigabu et al. (2015b), Lawson-Lartego & Mathiassen (2016), and Kebede et al. (2015), implicitly argue that African countries such as Rwanda, Ethiopia, Uganda and Asian countries such as Bangladesh and Lao PDR are included in the category.

Furthermore, developing countries that have the goal to develop their own national entrepreneur of renewable energy innovations usually act to facilitate national innovators that most of them sponsored by government or actors that have linkages with governmental entities (Baerz et al. 2011). Simultaneously, financial incentives are usually applied to induce the local market (Gliedt et al. 2018). The main goal of those countries is to create their own technology that is more suitable for the local market (Arent 2017). One of the most visible policies to enhance this strategy is by determining the minimum percentage of local components for each pilot project or renewable energy installation in the country (Blum 2013; Pillai 2014). Ding et al. (2012), Bala (2013), and Dantas et al. (2018) argue that India is among the developing countries that has the potential to create its renewable industry which focusses on fulfilling its own market.

Developing countries frequently focus on being a destination of diffusion of novel green technologies

Most of the emerging countries usually need a long period of time to just stay as passive targets of diffusion of radical renewable energy innovation, before going in another direction, for example to create their own renewable energy industry (Elias and Victor 2005; Mainali 2014; Jain et al. 2017; Vidican et al. 2010). Subsequently, several literature reviews that are about green technologies in poor countries, for example (Tigabu et al. 2015a, 2015b; Vidican et al. 2010; Hussain et al. 2017; Lee and Lee 2018), show that in order to be a location for the successful commercialization of sustainable energy innovations, there are steps and processes that are usually undergone by emerging countries in developing their market for renewable energy technologies. The first step includes sporadic and limited pilot projects, the second step is more into scientific movements, and the final step is the requirement for fiscal intervention. The detail is as follows:

- The first step is that after the government's initial vision of introducing introduce novel green technologies, a very sporadic and limited number of demonstration projects that are mostly conducted by entities related to international innovators, government bodies, and public universities may take place (Isoaho et al. 2017; Mainali 2014).
- After the first step has gone well, a stronger vision is then issued by the policy maker. In this level, the strategy is more scientific (Egbetokun et al. 2017). For doing so, R&D and knowledge sharing activities in order to generate a greater compatibility of the novel technology with local needs to be implemented (Kebede et al. 2015). The transfer of information dedicated to a broader range of stakeholders, for example local communities, local entrepreneurs, and international counterparts is also begun (Lin et al. 2013).
- The third stage takes place when the novel technology has experienced significant progress in terms of price and ease of application by end-users so that there is an increase of the potential market in the country (Pillai 2014). In this level, government is strongly required to issue fiscal support as well as legitimacy for private sectors to widely commercialize the technology (Eller and Gauntlett 2017; Esmailzadeh et al. 2020).

A poor country may only have the possibility reaching the first or second step for being a market of green technologies (Tigabu et al. 2015b). The first level depicts a very high dependency on governments to create project initiatives because government related bodies have more capacity in term of resources, knowledge and finance in comparison to individuals or private companies (Kayal 2008). In addition, countries that are stuck on the second step usually experience a lack of efficient and effective links between actors at a time when they undergo knowledge sharing, and a lack of resources in conducting collaborations, especially in terms of finances and expertise (Tigabu et al. 2015b; Vidican et al. 2010). Weak, passive and fragmented but less heterogeneous type of actors, specifically refers to most of the activities that are implemented by academics, also challenges this step (Brem and Voigt 2009). In addition, there is a lack of a formalization of interrelationship between actors that usually creates a rather weak degree of intellectual protection during the second stage (Hekkert et al. 2011). Meanwhile, countries that achieve the third stage may also be exposed to several challenges, especially in the form of incompatible infrastructure, a lack of government capacity to provide subsidies and a lack of common vision between innovators to lobby the government (Hellsmark et al. 2016; Jacobsson and Johnson 2000). In addition, the cost of technology that is still more expensive compared to traditional fossil fuels impact on the levels of interest in local communities (Haase et al. 2013).

Dominant resource orchestration within innovation processes in developing countries

In cases of developing countries, studies done by Bittencourt et al. (2021), Esmailzadeh et al. (2020), Kebede & Mitsufuji (2017), and Mohammadi et al. (2013) show that in order to build up a connection among stakeholders, including in the renewable energy sector, triggers, such as the existence of and guidance from leading firms and political actors, are required. Those entities play a vital role in providing beneficial preconditions, for example by stating a vision or goal, inducing cooperation among stakeholders and deploying strategic policies. Related to this, Klerkx et al. (2015), Blum (2013), and Schiefer & Rickert (2013) explain that in most emerging countries, the government at the beginning indeed strives to set-up a strategic and conducive policy, including to strengthen linkages among multiple stakeholders and to determine the vision. However, as the programs are already running, the linkages which are already weak among various actors from the beginning could not perform optimally.

In order to explain the weak performance of innovation processes related to renewable energy technologies in emerging countries, Fadlallah & Madhok (2021), Wang & Wang (2016), and Bush et al. (2016) argue that a high dependency on potential leading actors, especially government and local industry leaders, creates less efficiency and success in innovation or diffusion technology if those potential prominent actors do not have the skills, knowledge, and materials in order to induce, guide or even control all steps of innovation movements. In addition, Boeing (2020) and Davidson et al. (2017) assert that prominent actors tend to focus on influencing a limited group of members which have similar values or socio-economic position with them because it is more efficient for them. For example, due to the huge political lobbying ability of incumbent firms, e.g. state owned companies or monopolists, the projects that come from the government program might go to groups belonging to incumbent firms (Dallamaggiore et al. 2016; Lee and Hess 2019). This might lead an inefficiency due to a lack of transparency and market competitiveness (Hockerts and Wüstenhagen 2010). In addition, the incompetency of opinion leaders to guide collaborative innovation networks that become more heterogeneous, leads an insignificancy in the existence of opinion leaders themselves because they fail to make members trust them (Nguyen et al. 2010). In this situation, the innovation processes later tend to depend only on various small scale and less sustainable interconnection between actors that creates and performs actions primarily based on their common interest and initiatives (Kivimaa et al. 2021).

3.6.3 Southeast Asia builds its smart grid system of innovation by being a potential market

Southeast Asia: The general picture

Southeast Asia consists of 10 countries that includes Indonesia, Malaysia, Thailand, Singapore, Brunei Darussalam, Lao PDR, Cambodia, Vietnam, Myanmar, and Philippines. The total population of those countries reached 649.1 million in 2018 (Feng et al. 2020). In addition, Indonesia had the biggest economic size with a total population of around 267 million and nominal GDP of 1,005 billion USD in 2018 (International Energy Agency (IEA) 2022b). Nevertheless, the country was among the nations in the region that had an average GDP per capita lower than 6,700 USD, beside Philippines, Myanmar, Lao PDR, Vietnam and Cambodia (Jammes et al. 2020).

Regarding the electricity sector, more than 80% of investment spending in the electricity sector in Southeast Asia was done by the monopolist (utility that belonged to the state) (Kimura et al. 2017b). Only around 15% of investment in the electricity sector was done by private big companies (National Renewable Energy Laboratory (NREL) 2020). In addition, the contribution of community initiatives to the total investment in the power sector is only around 5% (Wuester et al. 2018). Meanwhile, in 2018, They still had around 5% of the total population without access to modern electricity (McKinsey Global Institute 2018).

The electricity sector in most countries in Southeast Asia is a regulated industrial sub-division which has a vertically integrated system where the utility as the oligopoly of several licensed big and private energy suppliers (Arinalso et al. 2018). Simultaneously, the utility also acts as a monopolist because it has the authority to solely sell and set the retail price to consumers (European Union (EU) 2016). It also controls the transmission and distribution of electricity in the country (Armansyah et al. 2012). This situation may influence the potential of renewable energy adoption and integration because there are conceivable conflicts of interest between actors over incentives, social-economic benefits, and risk sharing (Hamdi 2019; Blum et al. 2015).

Southeast Asian countries, nevertheless, show their initiatives in increasing the contribution of renewable energy resources in their national energy mix. Table 3-9 shows that in 2017, Indonesia and Thailand achieved higher levels of development of their renewable energy sector than their neighbors. They successfully provided around 17-22% of national energy supply from renewables (International Energy Agency (IEA) 2022a). On the other hand, in 2019, in terms of the contribution of modern renewable energy in power generation, Vietnam was at the fore front reaching a share of almost 26% (Diaz-Rainey et al. 2021). Other countries that also experienced a noticeable performance of the renewable energy sector in their power system include Philippines (share =14.73%), Thailand (share = 13.35%) and Malaysia (share = 6.59%) (Veng et al. 2020; National Renewable Energy Laboratory (NREL) 2020). Indonesia, in this case, only had around a 6% contribution of renewable energy on its electricity sector. According to Association of South East Asian Nations (ASEAN) (2021), in 2019, the majority of renewable energy for electricity generation in Vietnam came from solar. In the same year, Philippines significantly increased its installed capacity of solar energy and geothermal that made the country surpass Thailand in terms of share of renewables in the power system (Sreenath et al. 2022). Meanwhile, for that year, Indonesia still had the largest installed capacity of geothermal power and bio-energy in the region (Association of South East Asian Nations (ASEAN) 2019). In addition to that, the majority of countries in Southeast Asia had already issued their aggressive plan in having more renewable energy in their energy sector. The average goal of the region was to have a share of alternative energy sources at around 30% of the national energy mix by 2050 at the latest (The United States Agency for International Development (USAID) 2019a; Jammes et al. 2020).

Table 3-9 Renewable energy situation in several Southeast Asian countries

Country	Contribution of renewable energy in the energy mix between 2017 and 2018 (in %)	Contribution of renewable energy in power generation in 2019 (Hydropower is excluded) (in %)	National renewable energy target
Indonesia	17	6.14	• Share of 31% in total energy mix by 2050 • 52% in electricity sector by 2030
Thailand	20	13.35	• Share of 30% total energy mix by 2037, • 36% in electricity sector by 2037, • 25% in transport fuel consumption by 2036
Vietnam	12	25.59	• 15-20% share of total energy mix by 2030, • Minimum 25-30% in electricity sector by 2050, • 38 GW solar PV and wind installed capacity by 203, • 4 GW offshore wind installed capacity by 2030 and 36 GW by 2045
Philippines	8	14.73	15 GW RE by 2030
Singapore	5	4.35	2 GW solar PV by 2030
Lao PDR	Less than 1	0.01	30% share of total energy mix by 2025
Malaysia	13	6.59	31% share of total energy mix by 2025

Source: (Jammes et al. 2020; International Energy Agency (IEA) 2020; Gnasagaran 2019; Budiman et al. 2021; The United States Agency for International Development (USAID) 2019a; Diaz-Rainey et al. 2021)

Smart grid collaborative movements in Southeast Asia: Duel with current technological regime

In Southeast Asia, eliminating energy poverty is still one of main objectives of the government (Cirera and Maloney 2017; Kuhlmann and Ordóñez-Matamoros 2017). Therefore, besides access to electricity, a guarentee to have reliable power supplies comes as the next target (Eid et al. 2016). On the other hand, due to the characteristic of their economic situation, the majority of poor people in Southeast Asian countries have very limited options to access modern green technology innovation, whereas the middle class might have a higher degree of opportunity to enjoy sophisticated green technologies (Eller and Gauntlett 2017). In addition to that, Mainali (2014), Arocena and Sutz (2002), and Blum et al. (2015), argue that many renewable energy projects in those emerging countries did not perform well because the technology is still significantly more expensive than conventional technologies. Subsidies for poor families in those less-developed countries, for example because of installing small scale PV installation, does not exist in general either (Jain et al. 2017; Kebede and Mitsufuji 2017). Even when the feed in tariff is introduced, the scheme only can be utilized by a limited number of big power companies which are the main suppliers of the utility (Mainali 2014). This factor may also create a specific characteristic of the market of green technologies that should be built in the region (Darmani et al. 2014). Moreover, the grid infrastructure of each country is specific in terms of physical design and operation due to historical factors or conditions of local consumers (Elias and Victor 2005). It can happen that the infrastructure is still less developed (Gliedt et al. 2018). With those market characteristics, plus the possibility of a lack of capacity to explore and reconfigure the innovation by themselves, those countries may only be able to be passive potential consumers of novel technologies (Byrne et al. 2012; Ecuru 2013).

In Southeast Asia, smart grid development focuses on the implementation of pilot projects that are controlled by the utility /monopolist (du Pont et al. 2019). The type of technology used in these cases includes microgrids due to their potential to promote a more decentralized management of the utility (Kamsamrong 2019; Allotrope Indonesia 2017; Chawla et al. 2018). In addition, on site demonstration projects of smart grid technologies that offer opportunities for consumers to play a more active role in the electricity sector through various technologies or applications also take place in the region (Kimura et al. 2017a). In this situation, utility and government may play on the opposite side of consumers because it challenges the current technological regime (Arifin 2019a). Nevertheless, new business models with new pricing mechanisms are several potential outcomes of smart grids (Asian Development Bank (ADB) 2018).

Between 2009 and 2014, several countries in Southeast Asia, including Indonesia, Vietnam, Malaysia and Singapore, established their plans for implementing smart grid technologies (Association of South East Asian Nations (ASEAN) 2015; Asean Centre for Energy (ACE) 2015). Their initiatives were aimed at building up a more decentralized power system, especially in campuses, industrial territories and rural areas, improving grid efficiency and reliability, and enhancing two-way communication between electricity suppliers and consumers (Bae 2012; Allotrope Indonesia 2017). The characteristics of smart grid implementation in Southeast Asia are as follows:

- Indonesia, Malaysia, Philippines, Thailand, Singapore and Vietnam are countries that have a tendency to focus as a market or target of the commercialization of smart grid innovations from abroad (Asean Centre for Energy (ACE) et al. 2018). The process of diffusion of those technologies is mainly led and controlled by the state-owned utility, except for Singapore which has no monopolistic electricity market (Wuester et al. 2018).
- The type of smart grid technologies that are mostly introduced include smart microgrids which focus on distribution automation, smart meters for demand side management, and smart meters for PV prosumers (The United States Agency for International Development (USAID) 2019a; Menke 2013; Arifin 2019b; Hirsch et al. 2015). Southeast Asia also has several initiatives for smart cities, electric vehicles and smart inverters, but those technologies are not mentioned as a priority for the government in their smart grid vision until the end of 2019 (International Renewable Energy Agency (IRENA) 2017; Nagpal and Hawila 2018).
- Project implementation of smart microgrids and demand-side management projects in Southeast Asia are mostly carried out through collaborations between international technology suppliers, utility/monopolist, public research centres or universities and energy policy makers (Arifin 2021b, 2020a). The activities of stakeholders are mostly in terms of knowledge exploration and generating the possibility to re-develop the technology to be more suitable to the local conditions (Giriantari and Irawati 2016). In cases of microgrid, barriers for adopting this technology include difficulties of project developers in creating efficient and effective contact and collaboration with the utility, since it still has its own interest in pertaining its current technological regime (Deutsche Gesellschaft für Internationale Zusammenarbeit 2013; Leeprechanon et al. 2011). The problem is also on the demand side, where capacity to access the technology is very low and a project without subsidies is very hard to be sustainable (Lontoh et al. 2016).
- Meanwhile, smart meters for PV prosumers are mainly installed in middle-high class residentials, public offices, campuses, and industrial parks (The United States Agency for International Development (USAID) 2019b; Badan Pengkajian dan Penerapan Teknologi (BPPT) 2017; Vithayasrichareon 2016). In Indonesia and Vietnam, the utilization of the smart meter by end-users between 2017-2019 was supported by fiscal incentives from the government through net-metering schemes (German Federal Ministry for Economicy Affairs and Energy (BMWi) 2016; Citraningrum 2019; Rauch 2014). Net metering refers to a license given by government or utilities for owners of on grid - distributed renewable energy generations to send their excess electricity production to the grid, so that at the end of each billing cycle those owners receive their net credit (Riva Sanseverino et al. 2020; International Renewable Energy Agency (IRENA) 2020). In this context, Hamdi (2019) and Gielen et al. (2017) assert that the current regulation in the region still mismatches the expectation of prosumers, for example complex procedures

to attain the license to install the technology. Policy uncertainty, especially due to a lack of transparency from the state-owned utility/monopolist and its conflict of interests in sustaining the current traditional energy regime, as well as existence of fossil fuel subsidies, make this technology still unattractive (Haryadi et al. 2021).

3.7 A summary of the literature review and derived conceptual framework

3.7.1 A summary of the literature review

The literature review reveals that there are still critics towards the TIS approach. They include its lack of bottom-up investigation to describe decentralized activities of its elements, a lack of further explanation about the formation process of a TIS as well as a limited analysis about the potential existence of its builders. On the other hand, its shown that innovation networks conceivably act as starting points to form and execute the functions of a TIS. For more details, there are several elements that influence an innovation network in scaling-up in order to handle a systemic function, including its goals, resources orchestration, intervention of leading actors, and engagement of its members in performing TIS functions. Furthermore, in the context of a collaborative innovation strategy for green technology, it is shown that the majority of developing countries, especially in Southeast Asia, act as the market of the novel innovation. The composition of actors in creating innovation ecosystems for renewable energy, especially in the context of emerging countries, is also rather homogenous, usually being dominated by government related organizations, public universities and state-owned utility. For more details, Table 3-10 provides the summary of literature as follows:

Table 3-10 Summary of literature review

Summary	**Based on**
• Number of literature reviews that specifically and explicitly utilize innovation networks as indicators for comprehensively analysing TIS evolvement, especially in developing countries, is still limited. • A study concerning innovation networks may enable a deeper and more comprehensive investigation about the formation and operation mechanism of TIS by paying attention to existing leading actors as well as process evolvement of the system based on bottom-up analysis.	(Musiolik et al. 2012; Musiolik 2012; Nilsson and Sia-Ljungström 2013)

• The first steps in order to examine the existence of an innovation network is the detection of available or ongoing interactions of a broad range of actors at level collaborative projects. Those projects can then potentially be pooled into specific innovation nexuses. • Innovation nexus that might enable interlinkages among stakeholders for handling disruptive innovations can generally be divided into three categories, including business-oriented networks, knowledge-oriented networks and government/intermediary-facilitated networks.	(Cantner and Graf 2006; Gretzinger et al. 2010; Mao et al. 2020; Howells 2006)
• Initiation and organization of resources of innovative collaboration arrangements, especially in developing countries, are mostly dominated by a limited number of stakeholders, for example policy makers, universities or incumbent firms.	(Bittencourt et al. 2021; Batterink et al. 2010)
• Regulatory frameworks, demand conditions, and compatibility of infrastructure that might be enabled by leading actors are more important than consensus management of collaborative network as factors for enhancing the success of collaborative projects in developing countries.	(Kebede and Mitsufuji 2017; Dhanaraj and Parkhe 2006; Siegel and Strong 2011)
• Collaboration projects pooled in a specific innovation network related to green technologies in developing countries are conceivably influenced or steered by leading actors which are mainly government-related organizations. • The intervention of leading actors may either enable the evolvement of functionality of innovation nexus or create barriers for stakeholders to continue their movements. • In the context of renewable energy technology, leading actors that include policy makers, utility/monopolist and research organizations, have different goals, capacity and strategy in influencing their network.	(Suurs 2009; Geels 2014; Pushpananthan 2022; Hargreaves et al. 2013; Kivimaa et al. 2019; Hoogma 2000; Schiefer and Rickert 2013)
• Each innovation network potentially performs functions of system of innovation through collective actions, such as conducting R&D and knowledge sharing activities and creating legitimacy for the novel technology.	(Davidson et al. 2016; Bergek et al. 2008a; Alotaibi et al. 2020)
• Each innovation network may have different levels of achievement in terms of the implementation of niche experimentation due to specific characteristics of the novel technology chosen as the priority within the network and capacity of stakeholders in developing and commercializing the technology.	(Loorbach and Van Raak 2006; Raven et al. 2011; Caniels and Romijn 2006; Suurs and Hekkert 2009)

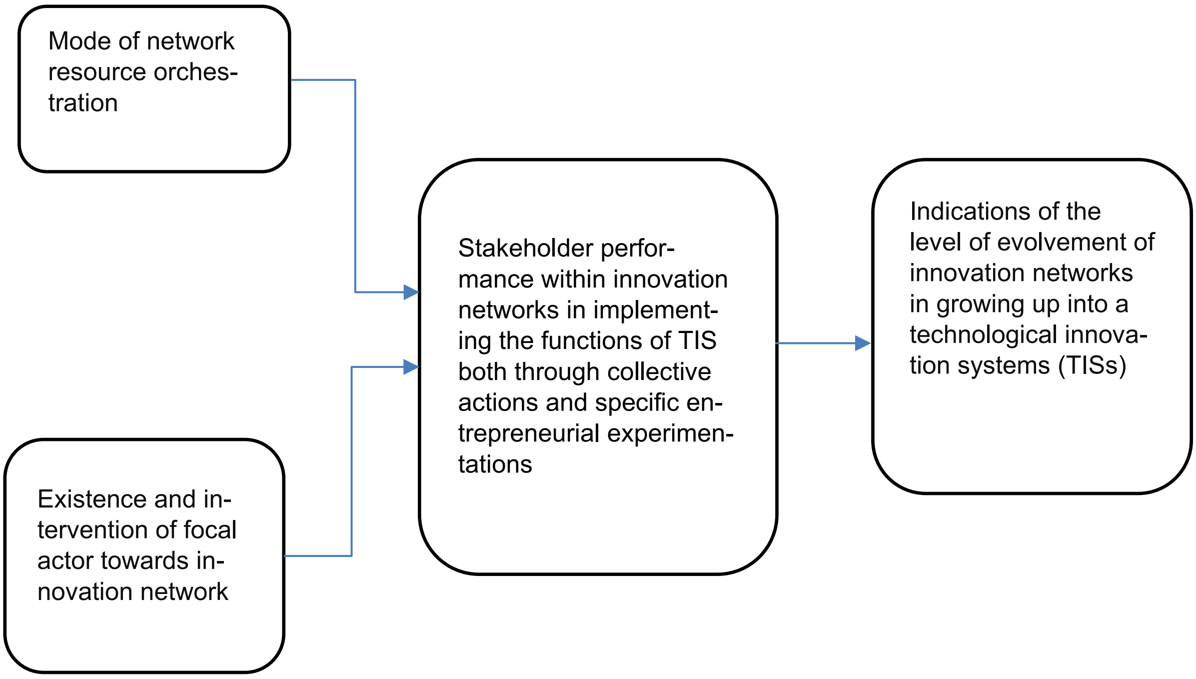
Source: Author's compilation

3.7.2 Restatement of the research aims and conceptual framework

The aim of this study is to analyse the evolution of collaborative movements grouped in innovation networks in building and operating technological system of innovation that empowers smart grid technologies for enhancing a more sustainable power system in Southeast Asia, especially in Indonesia. Based on the literature review, the conceptual framework for the thesis illustrates that the indicator of the level of the evolution of innovation networks in growing into a technological system of innovation can be seen through three factors:the mode of resource orchestration of the innovation network, the intervention of leading actors, and the achievement of innovation networks in fulfilling functions of a technological innovation system (TIS).

In addition, based on the literature review, the conceivable relationships between elements on the conceptual framework provided in Figure 3-6 can be illustrated as follows:

- The better characteristics of resource orchestration of the innovation networks in illustrating more active contribution and flexibility of majority stakeholders in providing and deploying common resources within networks, the better performance of stakeholders in implementing functions of TIS, thus, the higher the likelihood of the level of development of innovation networks in growing into TISs.
- The more existence and intervention of leading actors in providing supportive environment for stakeholders within their networks, the better performance of stakeholders in implementing the functions of TIS, thus, the higher the likelihood of the level of development of innovation networks in growing into TISs.
- The higher level of stakeholders' achievement in innovation networks in implementing functions of TIS so that the novel technology can be commercialized to a large scale, the higher the likelihood of the level of development of innovation networks in growing into TISs.



Source: drawn by author by compiling concepts from (Freeman 1989; van de Ven 2005; Kogut 2000; Nilsson and Sia-Ljungström 2013; Kanda et al. 2019; Carlsson and Jacobsson 1997; Rogers 1983)

Figure 3-6 Conceptual framework: Schematic view of innovation networks as an indicator of creation and evolution of technological innovation systems (TIS) in Indonesia

In the next chapter, the details about methodology, instruments and techniques for data collection for the analysis are presented. The scope and limitation regarding the research are also explained.

4 Research Methodology

This chapter presents the research methodology applied in the research. A mixed research method was employed in the study. In addition, the chapter describes smart grid movements in Indonesia as the focus region of the study, by taking a specific view of the case studies that include three networks for smart grid movements, namely a political decision-based network informally initiated by the energy policy maker, a business network informally initiated by a state-owned utility and a knowledge network informally initiated by the education policy maker. Other various aspects related to research methods, such as scope and boundaries of study, data collection method and instruments, and data analysis are also captured in the chapter.

4.1 Research approach

The research utilized a mixed research approach. Mixed methods research refers to a single study in which the researcher gathers and interprets data, puts together the results as well as draws conclusions by applying both quantitative and qualitative method (Creswell 2014). It allows collection and analysis of data from various sources in a single piece of research. It accommodates both ''post-positivism and interpretivism'' because it incorporates qualitative and quantitative information from different perspectives or scientific lenses in order to optimally explain a phenomenon (Regnault et al. 2017; Ivankova et al. 2006). According to Neri & Kroll (2003), the method allows researchers to undertake exploratory research as a result of the limited information available in the literature but at the same time they can formulate research questions that can be tested or confronted with general theory. In this level, ''closed-ended'' quantitative data offer information about the size or dimension of the searched topic of the study based on multiple responses from respondents, whereas ''open-ended'' qualitative data gained from either interviews or desktop research enhance a deeper understanding about a particular phenomenon as well as open up possibilities for predicting the future of the object of the research (Dawadi et al. 2021; Johnson 2014a). In other words, mixed method research gives more validity to the study because both qualitative and quantitative data support each other (Zohrabi 2013). For example, qualitative data can be used to enrich analyses based on quantitative findings because it could provide policy makers a detailed explanation of the problems, including the scale, characteristics, and interrelationship between problems (Kroll and Neri 2009; Halcomb and Andrew 2009).

In addition, multiple case studies were applied in the research. According to Yin (2003), case research offers a better explanation of the background and the complex relationship between elements of the object of the study, therefore it usually provides stronger findings and can deal with more complex research questions. Meanwhile, Dubois & Gadde (2002) argue that multiple cases are used to compare the findings, enhance the accuracy of the data and reveal more unknowing aspects of the object of study. Multiple types of data are useful in order to broaden the range of the investigation as well. Furthermore, Ababacar Sy Diop & Liu (2020), Bass et al. (2018), and Baxter & Jack (2015) assert that a collective case study allows the researcher to conduct investigations within a specific setting and across settings. By not only examining the uniqueness of a certain case, this method also enhances the research to analyse the likeness, differences or correlation between cases. Therefore, reliable and solid findings may be generated from this method. Nevertheless, the approach is usually time-consuming and very costly in order to generate a deeper understanding of the object being observed (Rini 2019; Starman 2013). For example, some studies may involve learning about the backgrounds of the object of study, including the educational or emotional situation, beliefs, and hobbies, before starting to interpret any information that is generated from him (Sinha 2017). Moreover, the problem is that case studies may provide results that are not generalizable because they involve examination of a small data set. However, case studies are still able to represent a deeper and more comprehensive confrontation between the theory and the data generated from the population within a specific context or scope of the study (Larrinaga 2016; Takahashi and Araujo 2019; Zach 2006).

Furthermore, multiple sub-units of analysis were also deployed for each case study in the research. In addition, the research adopted different frameworks or boundaries in examining each sub-unit of analysis. This approach is also called ‘’embedded case study’’ (Yin 2003; Mfinanga et al. 2019). It enhances the researchers to deepen their exploration about a particular object as a system by defining the background, form and process of its multiple intercorrelated sub-units (Scholz and Tietje 2002). According to Runeson & Höst (2009) and Chaiprasurt (2019), it is possible for each case study to consider more than one sub-unit of analysis in order to enrich the exploration. It also contributes to the validity of the research because it combines more variations in the source of data (Yin 2003).

4.2 Research setting: Smart grid network initiatives in Indonesia undertaken by three government-related bodies

This study might be best termed as a piece of research to elaborate on the technological innovation system (TIS) approach within developing countries as a specific research setting. Previous studies about the system of innovation of a specific technology field in developing countries still mostly concentrate on determining the general or national picture of the system’s structure to converge its common characteristic in order to set a generic policy guidance (Arocena and Sutz 2002; Kebede and Mitsufuji 2017; Lee and Lee 2018; Mohammadi et al. 2013; Wesche et al. 2019). Thus, the research extended the analysis of previous literature by providing a more bottom-up approach in studying the development of TIS in the context of developing countries through examining the role of innovation networks as a specific indicator that potentially initiates and executes functions of the TIS.

Furthermore, this thesis used Indonesia as the region of study. Although Indonesia has the largest sized economy in Southeast Asia, in 2013 it still had less than 98% electrification rate and around 66 million people still had problems in having reliable electricity (Lauranti and Djamhari 2017; Rai 2018; Association of South East Asian Nations (ASEAN) 2015). Geographically, Indonesia consists of many small and big islands, making nationalised grid expansion very expensive. In addition, regions in Indonesia which had been connected to the national grid (Sumatra Island, Java Island, Bali Island) still faced problems related to the high potential of blackouts, an inefficient transmission/distribution system, and a high dependency on fossil fuels (Prastawa et al. 2017; Blum 2013). On the other hand, Indonesia has a significant potential for renewable energy. According to International Energy Agency (IEA) (2013b), in 2030, Indonesia would be the country with the biggest investment potential for developing a renewable energy power system in Southeast Asia. The total potential energy produced from renewable energy in Indonesia would reach more than 400 TWh. Bioenergy (biogas and solid biomass), geothermal, hydropower and solar photovoltaic are types of renewable energy technologies that could be widely developed in the power sector in Indonesia (Asean Centre for Energy (ACE) 2015). In addition, wind and tidal energies also have some share of the potential to be developed in Indonesia (Asian Development Bank (ADB) 2016). In this context, smart grids have the potential to enhance more renewable energy as well as improve the current conditions of the power system.

Between 2009 and 2019, several type of smart grid technologies had been introduced in Indonesia. Those included off-grid and on-grid hybrid power system management, smart microgrids, smart meters for demand ma-nagement and smart meters for PV prosumers (Asean Centre for Energy (ACE) et al. 2018; Gnasagaran 2019; Numata et al. 2018). In addition, various stakeholders were involved in smart grid projects in Indonesia, including state -owned utility, policy makers, non-governmental organizations, smart-grid firms, academics as well as private early adopters (Allotrope Indonesia 2017; Benarto 2019; Liebman et al. 2019). In the early 2010s, three government related bodies, including the Indonesian ministry of mineral and energy resources, state-owned utility and the Indonesian ministry of research and higher education, explicitly announced their initiatives that might implicitly or informally encourage smart grid collaboration movements in the country. Those three organizations were not just average bodies. They were powerful in terms of capacity in implementing smart grid projects as well as influencing other stakeholders. Table 4-1 shows that those three organizations had the highest point in terms of ability in conducting consultations/knowledge dissemination, organizing training/education, implementing on-site pilot projects and issuing regulations. Other types of stakeholders that also have a high potential capacity in performing smart grid activities in Indonesia are universities or research centres, as they are able to circulate knowledge and providing training or education independently. They also have competencies in initiating or implementing collaborative demonstration projects as long as there is a license from the energy policy maker, education policy maker, and the state-owned utility. Meanwhile, smart grid technology suppliers may have expertise in disseminating knowledge independently. However, for implementing other activities related to smart grids in Indonesia, those companies strongly need a license, a contact, as well as collaboration with policy makers, the utility and academics. Other stakeholders, such as NGOs, supranational organizations, mass media, financial entities, private individuals and business entities related to smart grid do not have any power to implement their activities independently without a license and co-operation with policy makers and the utility.

Table 4-1 List showing the capacity of various stakeholders within smart grid movements in Indonesia in implementing projects as well as influencing other stakeholders

Capabilities / Type of organization	Organizing formal business consultan-cies/ formal events for knowledge dissemina-tion	Trai-ning/---educa-tion in a formal forum in-volving various parties	Testing pilot project	Issuing national policy (finan-cial/ tech-nical) using state-budget	Total check marks	Score based on number of check marks
Private Smart Grid supplier	√√√	√√	√	x	√√√√√√	6
Universities /R&D Centres	√√√	√√√	√	x	√√√√√√√	7
Higher Education policy maker & Energy policy maker	√√√	√√√	√	√√√	√√√√√√√√√√	10
State owned utility/ monopo-list/incumbent firm	√√√	√√√	√√√	√√	√√√√√√√√√√√	11
NGOs	√	√	√	x	√√√	3
Private/Individuals	√	x	√	x	√√	2
Financial Entities	√	√	√	x	√√√	3
Business entities related to smart grid/RE	√	√	√	x	√√√	3
Mass Media	√	√	x	x	√√	2
International Partners (UN/ASEAN/EU/foreign govt.)	√	√	√	x	√√√	3

Note:

X : do not have capacity to conduct independently

√ : only through cooperation with other parties (local firms/policy maker/research centres) and permit from the government, especially education policy maker and energy policy maker, and from the utility/monopolist as well

√√ : only through a permit from the government, especially education policy maker and energy policy maker, and from the utility/monopolist as well

√√√ : implementation can be done independently

Source: (Arifin 2019a; Pramono et al. 2020; Hamdi 2019; Outhred and Retnanestri 2015; Asian Development Bank (ADB) 2016; Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2008; Indonesian Ministry of Research and Higher Education (IMRHE) 2010b, 2019; Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2019a, 2020c)

Innovation network initiatives for smart grids in Indonesia

Initiation of innovation networks by focal actors enhances potential mechanisms for stakeholders to be coupled into a specific hub or central connection that is within the circle of those focal actors (Howells 2006; Gretzinger et al. 2010). Due to their capacity in providing information or resources, focal actors are able to contact and influence other stakeholders from the hub through gathering them into various collaborative activities (Dhanaraj and Parkhe 2006; Ahuja 2000). Meanwhile, opportunities in terms of funding or social-political benefits owned by the hub created by focal actors may also attract existing independent collaborative projects or multiple groups of individuals to connect to the hub (Rothwell 1994; Hagedoorn 1993). In this study, three networks for smart grid movements that include a political decision-based network informally initiated by the energy policy maker, a business-based network informally initiated by state-owned utility and a knowledge-oriented network informally initiated by the education policy maker, were used as case studies. For more details, each case study covered mainly two sub-units of analysis, including the performance of the network at an aggregate level and the performance of the network at a micro level through its specific on-site entrepreneurial experimentation.The macro-level overview of each network discussed the management of the network resource orchestration, the potential and actual intervention of leading actors and the overall performance in fulfilling various functions of a TIS. Meanwhile, examination of a specific entrepreneurial experimentation paid greater attention to the creation of motor innovation that was aimed at implementing various functions of a TIS at a grassroots level.

1). A political decision-based network for smart grids informally initiated by the energy policy maker (Case 1)

Between 2008 and 2019, the Indonesian ministry of mineral and energy resource implicitly built and began to supervise its innovation network related to smart grids. The policy maker acted as an intermediary between financial entities coordinated by the Indonesian ministry of finance and project executors (Arinalso et al. 2018). The first initiative to enhance linkages between stakeholders was issued in 2008. In that year, the energy policy maker declared the national electricity plan that focused on increasing national electrification ratio through enhancing links and cooperation between stakeholders (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2008). Then, in 2012, the entity issued programs for energy management (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2012b). In both agendas, the utilization of ICT based technologies were welcomed to assist the implementation of those projects (Giriantari and Irawati 2016). In 2016, the entity attempted to deploy its network to implement various on-site demonstration projects in rural and remote areas (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2016b). In the program, smart microgrids were introduced in several remote islands (Hirsch et al. 2015). The actors of the program were mainly from state-owned utility, local government, public universities and research centres, technology suppliers and NGOs (Asian Development Bank (ADB) 2016).

Regarding its historical background, the energy policy maker already had had a long story in supervising the development process of the national electricity sector. In 1984, in line with massive electrification process in the majority of regions in Indonesia which encouraged hydropower resource deployment, the entity created a new office (the so-called directorate general of electricity and renewable energy) in order to facilitate technology diffusion in the country (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2022a). Nevertheless, since 1998 it changed its strategy to be regulator as well as significant innovation planner in the electricity sector. At this level, it divided the Directorate General of Electricity and Renewable Energy into two sub-divisions: sub-directorate of electricity and sub-directorate of renewable energy. This was done to explicitly separate the actual power sector at that time which was mainly based on conventional energy and movements that were aimed at introducing modern renewable energy technologies (Outhred and Retnanestri 2015). The strategy was somehow more encouraged in 2010, when the energy policy maker decided to erase the director general of electricity and renewable energy and give a new name to those two sub directorate general as directorate general of electricity and directorate general of renewable energy (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2022b). This meant it could better protect the continuity of conventional power systems but at the same time attempt to give a legitimacy to renewable energy innovation activities, including smart grid development (Gielen et al. 2017). In addition, the strategy was aiming at separating two different energy regulations: fiscal and non-fiscal regulation for the electricity sector that tended to support the electricity state-owned utility, and fiscal and non-fiscal regulation for encouraging and governing renewable energy development and deployment in Indonesia (Liebman et al. 2019; van der Veen 2011).

2). Business-based networks for smart grids informally initiated by the state-owned utility (Case 2)

An initiative to create connections among actors of smart grid movements in Indonesia was also informally and implicitly created by the state-owned utility (*Perusahaan Listrik Negara).* In 2015, the company issued its smart grid roadmap. The vision aimed to increase its business performance and technical capability of national utility through development and deployment of smart grid technologies (Asean Centre for Energy (ACE) et al. 2018). In addition, since 2016, the incumbent company had started its R&D projects and demonstration projects with the majority focussing on the introduction of smart meters for demand management and smart meters for Rooftop PV prosumers (Vithayasrichareon 2016; Tambunan et al. 2020; Suhartanto 2014).

From the 1980s to 2019, the utility showed its strategy to embrace smart grids through its innovation network. It acted as an innovation follower and participant at the beginning and then changed its strategy to play the role of innovation controller supported by the energy policy maker.

The state-owned company which was also the monopolist of the electricity sector in Indonesia, started to pay attention to renewable energy by firstly administering all the hydropower electricity projects in Indonesia in the 1980s (Perusahaan Listrik Negara (PLN) 2022). In the following decade, the state-owned corporation acted more as an innovation follower by being active in participating in sharing knowledge and information about renewable energy in Indonesia (Arifin 2021d).

Then, in the beginning of 2000s, the company supervised and controlled various renewable energy projects in Indonesia, especially for micro hydro pilot projects in rural areas (Asian Development Bank (ADB) 2018). In 2008, a prepaid metering system was successfully introduced by the company (Asian Development Bank (ADB) 2017). It enabled consumers to have a prepaid electricity agreement and paid it in advance. In the following year, a mobile application (the so called '' PLN Mobile'') was also launched by the enterprise to provide actual information to consumers about electricity consumption and a bill. It also have quick access to consumers to check and reload electricity credit balances of pre-paid metering users (Budianto and Saragih 2011). In 2010, together with the policy maker for the energy sector and the Agency for the assessment and application of Technology or *Badan Pengkajian dan Penerapan Teknologi* (BPPT), the enterprise was involved in renewable energy projects in remote islands in Indonesia using microgrid technology. One of them was the Sumba Microgrid Island Project that was launched in 2012 (Prastawa et al. 2013). In those projects, the company acted as the local and national grid owner as well as the adopter of the new innovation (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2018). In addition, between 2014 and 2019, the company focused hand in hand with the energy policy maker in regulating movements of smart grid deployment in Indonesia, especially smart meter for residential PV prosumers (Benarto 2019; Ali et al. 2008).

3). Knowledge-oriented network for smart grids informally initiated by the research and higher education policy maker (Case 3)

The knowledge-oriented network for smart grids was implicitly initiated by the Indonesian Ministry of Research and Higher Education through the White-book – National Research Plan 2014-2016 (Dewan Riset Nasional (DRN) 2013). The document was issued in 2013 and was aimed at developing the national electricity sector through research and development activities for ICT-based technologies, especially those that were dedicated to the topic of decentralized power system. Through the plan, various smart grid scholars in Indonesia were provided with opportunities to work collaboratively through funding schemes facilitated by the research and higher education policy maker. Before issuing this initiative, the entity firstly and specifically issued research programs for the energy sector in 2004 through the national research plan for the renewable energy sector 2005-2025 (Indonesian Ministry of Research and Higher Education (IMRHE) 2004).

As for its historical background, between the 1960s and early 2000s, the entity existed to bring together all public research institutes as well as research units under universities and has been the intermediary between the regime and the academic realm (Indonesian Ministry of Research and Higher Education (IMRHE) 2018). Nevertheless, there were ups and downs regarding the capability of the focal entity due to changes in the political regime.

In the 1960s, it had a role in overseeing all public research institutes in Indonesia. It shared the vision and program of the current political regime to all national researchers (Fadli and Kumalasari 2019). Subsequently, in 1978, it was given a mandate to strengthen the network among research centres that were related to the national strategic industries (Okta 2022). In addition, reverse engineering was one of the main approaches utilized by the education policy maker to accelerate the development as well as the acquisition of novel technology in Indonesia (Ariftia 2014). However, as the political uprising happened in 1998, the function of the entity was reduced dramatically. It began to lose its authority to connect to the state-owned companies (Hutabarat 2018). Between 1998 and 2002, the body acted only as a coordinator of all public research institutes in Indonesia without much significant economic and political power for imposing any national research vision or strategy (Sunarso 2012).

Subsequently, the body regained more political power to lead national research activities as the central government issued national research, and the Development and Application of Science and Technology Act (*Undang-Undang SISTEKNAS No. 18/2002*). The document bestowed the entity to be able to act as the center of the national network for innovation (Ministry of State Secretariat of Republic Indonesia (MSSRI) 2002). It also was given the sole authority to either accept or reject a research permit to any national and international research activities that would be undertaken in Indonesia (Indonesian Ministry of Research and Higher Education (IMRHE) 2019).

4.3 Boundaries and scope of the research

This research can be described with the following boundaries and scope:

- The research focused on examining smart grid activities in Indonesia from 2009 to 2019.
- The population stakeholders of the research were experts of smart grids from multidisciplinary backgrounds that were involved in any activities organized by the Indonesian smart grid initiative (*Prakarsa*

Jaringan Cerdas Indonesia or (PJCI)) between 2015 and 2019. In addition, a snowball sampling method was utilized in the study.

- This study examined three informal innovation nexuses in Indonesia, in which collaborative activities related to smart grid technologies of the population were potentially coordinated. Those networks included an intermediary-based network informally initiated by the energy policy maker, a business-based network informally initiated by a state-owned utility and a knowledge-oriented network informally initiated by the education policy maker.
- Some definitions used in the study during data collection processes:
  - Smart grids in the study refer to those defined by (International Renewable Energy Agency (IRENA) 2015). The research focused on four categories: (1) information collectors to measure the performance of electricity system components (e.g., smart meters), (2) information assemblers, displayers and assessors (e.g., advance electricity pricing, renewable resource forecasting), (3) information-based controller (e.g., smart inverters) and (4) energy/ power resources (e.g., microgrid, virtual power plant).
  - A technological innovation system (TIS) for smart grids in this study was a set of networks of actors that jointly interacted to contribute to the generation, diffusion and utilization of smart grid technologies.
  - Innovation networks for smart grids were a nexus where interactions between actors in order to engage activities for smart grid technologies took place.
  - Collaboration arrangements for smart grid activities were actions to carry out idea generation & mobilization, research & development and commercialization of any type of smart grid technologies completed by a small group of various actors that belong to a particular innovation network.

4.4 Data collection method

4.4.1 Theorized variables and approach for data collection

Table 4-2 illustrates the details of the type of data and approach to data collection. In general, each variable is collected both in the form of quantitative and qualitative.

Table 4-2 Details of studied variables and strategy for data collection

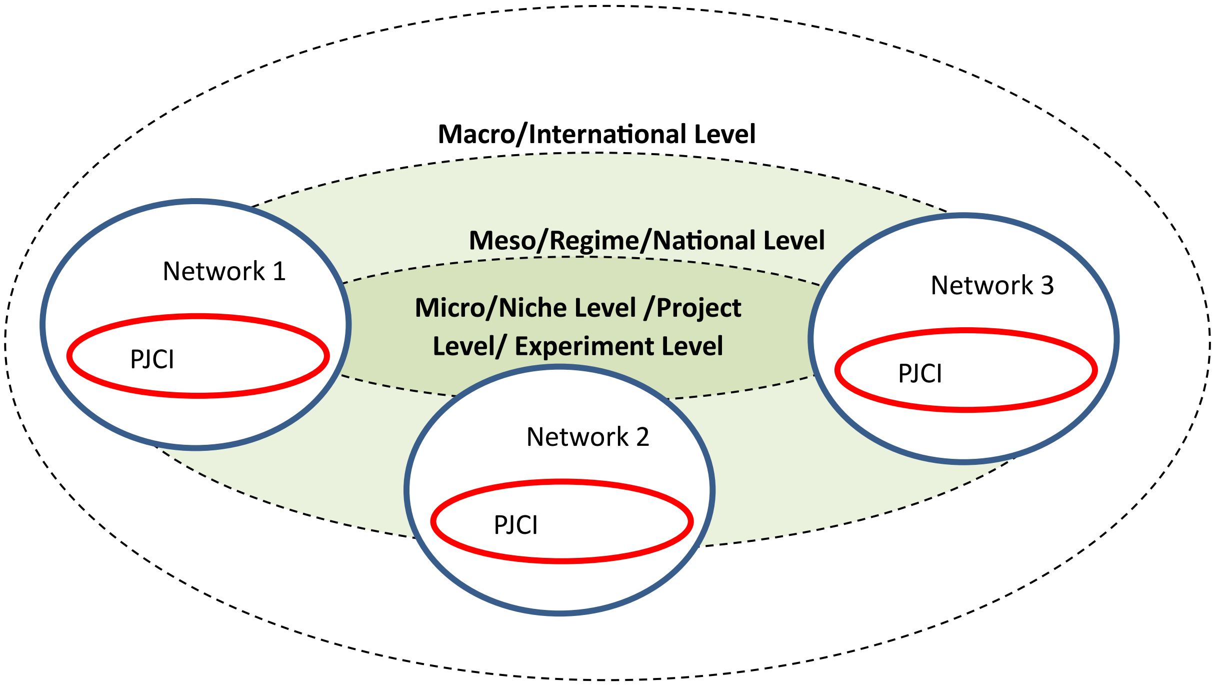
Broader category of factors	**Variable /Data that will be presented (comparison between three network cases)**	**Type of Data**	**Source**
Mode of orchestration of innovation network	• Initiation mode of collaborative projects • Access of stakeholder in utilizing common collected resources and generated outcomes of collaborative projects	Quantitative and Qualitative	On-line survey, interview, and desktop research
Existence and intervention of focal actor (incentives/ investment) towards collaborative arrangements	• Potential position of potential focal actors in influencing their network based on their linkages with other stakeholders (degree of centrality, betweenness centrality and closeness centrality) • Actual intervention of focal actors in either building or hindering their network	Qualitative and quantitative	On-line survey, interview, and desktop research
Performance of innovation network in fulfilling functions of TIS	General coverage of collective actions: including in form of R&D projects, knowledge sharing activities, involvement in policy making, on-site pilot projects, and lobbyings	Qualitative and quantitative	On-line survey, interview, and desktop research
	Specific coverage of entrepreneurial experimentation's case	Qualitative	interview, and desktop research

Source: Own depiction

4.4.2 Population and sampling method

One of the main challenges faced by the mixed method used in the study is related to the limited research time and budget. In addition, the population of experts of smart grids in Indonesia is still not well defined. Therefore, the study focused on the population of smart grid experts in Indonesia that were at least involved in activities organized by the Indonesian smart grid initiative (*Prakarsa Jaringan Cerdas Indonesia* or (PJCI)) between 2015 and 2019. PJCI was the only formal facilitator or platform for smart grid movements in Indonesia that had a license from the Indonesian ministry of law and human rights to enhance connections between stakeholders of smart grids in Indonesia (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2020a). The advantage of PJCI was that it conceivably facilitated meetings or contacts between multiple actors that came from different backgrounds in Indonesia.

In this study, however, the list of all participants of the events in the time period was not granted to the researcher by the management of the Indonesian Smart Grid Initiative. Nevertheless, lists of the names of key contacts of three different case studies were provided by the organization. A further problem was that the majority of potential participants that had been contacted refused to be interviewed but had a willingness only to answer short and closed questions. Based on this, correspondences through on-line surveys were conducted by utilizing a snow-ball sampling method. To clarify, a snow-ball sampling method refers to a non-probability approach of selecting the sample of a survey to locate hidden populations or because objects of observations are difficult to access (Johnson 2014b; Naderifar et al. 2017). As for the qualitative phase, information was collected through desktop research as well as in-depth interviews by telephone, where four informants were selected for each case study. Furthermore, Figure 4-1 describes the scope of the population of the object of the study. It is within the circle coordinated by the PJCI, and the researcher took a sample from it. In addition, the sample covered multiple experts of smart grids in Indonesia that had experience in implementing smart grid activities either as actors in on-site experimental projects, as stakeholders at a national level, or as actors from outside Indonesia.



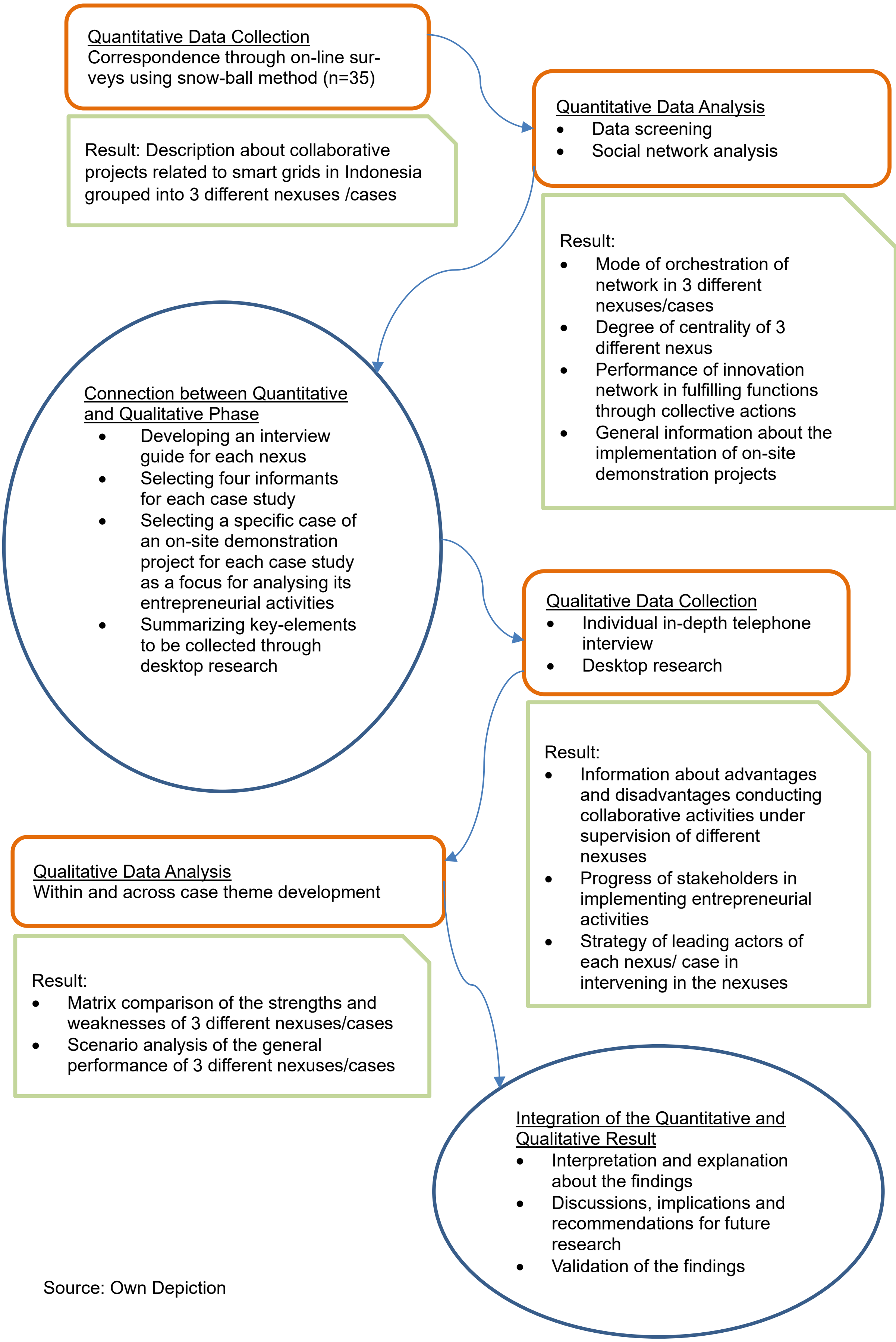
Note:
Network 1: political decision-based network led by the energy policy maker (Case 1)
Network 2: Business-based network led by the state-owned utility (Case 2)
Network 3: Knowledge-oriented network led by the education policy maker (Case 3)

Source: Own Depiction

Figure 4-1 Details of scope of population and sampling method in the study

4.4.3 Research steps

An explanatory sequential design was utilized in this study, where quantitative data collection and analysis was followed by the qualitative phase which consists of in-depth interviews and desktop research. According to Kroll & Neri (2009) and Neri & Kroll (2003), this approach enables the researcher to identify the proportion and characteristics of the objects of the study as well as to examine the general problems, impacts, and future plans of the activities of objects of the study through qualitative methods in a particular context. The quantitative data collection was completed through correspondences with participants that were followed by their contribution in answering on-line surveys facilitated by *Google.* Questionnaires with closed questions were used in the on-line survey to collect exclusive and quantitative data about the activities of participants of each group or case of innovation nexus. In addition, the author was interested in developing detailed, in-depth answers about the management and performance of the innovation nexus through in-depth interviews. Furthermore, data from secondary resources, such as scientific journals, books, and reports were collected to gain a variety of information that provides sets of research materials. Subsequently, all data gathered was combined and observed in order to check their validity and complementarity. Data integration in this research was undertaken through considering the findings from the quantitative phase for developing the interview-guide as well as variables or elements that should be collected through desktop research. Information that covered the steering processes of activities within the network, the role of leading actors and its impact, drivers and challenges of collaborative activities within the network were collected through the qualitative phase. In addition, specific questions about the development of certain entrepreneurial activities were also used in the process. In addition to that, desktop research was implemented for collecting information to refine the analysis about the condition of each group, including data about its internal policy and external factors that conceivably correlate. (See Figure 4-2).



Source: Own Depiction

Figure 4-2 Research steps

4.4.4 Data collection through on-line survey

Summary of questionnaire

There were a total of 33 questions in the questionnaire that were used in thre on-line survey. Allof the questions were multiple choice except for sections that collected information about identity and organizational backgrounds of participants. Below is a summary of the composition of questionnaire that cover variables that are analysed in the research:

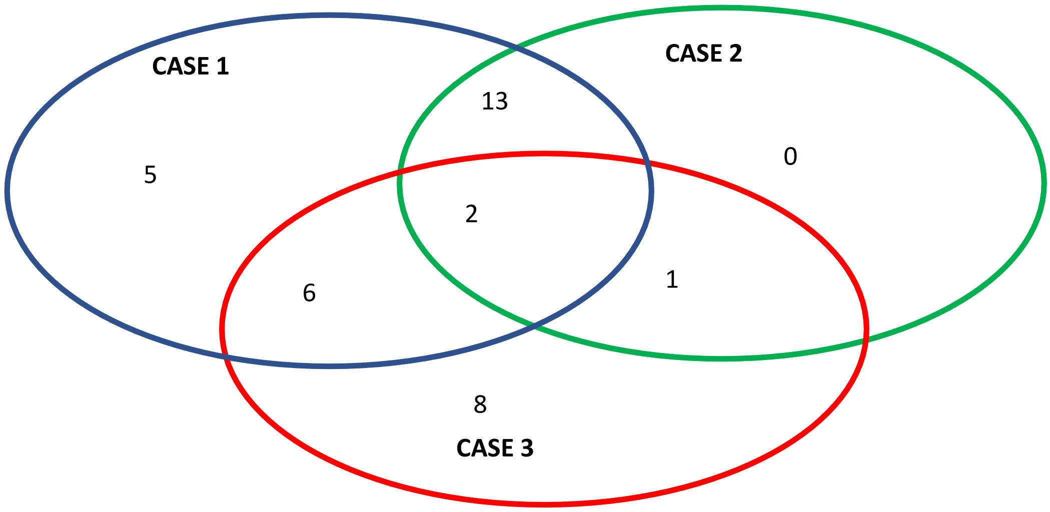
Table 4-3 Summary of contents of questionnaire for on-line survey

Topic	Questions
Identification of participant	1-5;10;11
Group of innovation nexus that participant belongs to	6
Interest of participants in certain types of smart grid technologies within the innovation nexus	7
Description of collaborative activities of participants related to smart grids in Indonesia, including partners, initiators, types of activities, duration and current status of activities	8-18
Initiation process and characteristics of resource deployment within collaborative projects of participants that are related to smart grids in Indonesia	19-20
Collective activities in fulfilling functions of technological innovation system (TIS)-smart grids in Indonesia, such as in the form of R&D projects, sharing knowledge and lobbying	21-24
General achievement in entrepreneurial activities of innovation nexus belonging to the participants	25-26
Perspective of participants towards importance of management of collaborative projects as key issue for implementing successful innovation processes for smart grids in Indonesia in comparison to other elements, such as political support, infrastructure, and public acceptance	27
Perception of participants towards their experience in managing their collaborative projects related to smart grids in Indonesia, especially in terms of handling elements that include geographical distance, power distribution, trust & commitment, coordination, and communication.	28-33

Source: Own depiction

Data of correspondents that participated in on-line survey

The total participants in the on-line survey were 35 experts (See Figure 4-3). In addition, those experts identified themselves according to the innovation nexus in which they were involved from 2009 to 2019. 57% of participants (20 experts in total) were active in more than one specific network. In addition, there was a significant number of experts (40% of total participants) that were active both in the nexuses under supervision of the energy policy maker (Case 1) and state-owned utility (Case 2). There was no expert that solely worked for the nexus led by the state-owned utility. In addition, total participants that were active between innovation circles belonged to the energy policy maker (Case 1) and concerning the academic domain (Case 3) were six experts (17% of total participants). Furthermore, only one participant (2% of total participants) was actively linked between academic nexus (Case 3) and the innovation circle of the state-owned company.



Note:

Case 1: Political decision-based based network led by the energy policy maker (Network 1)

Case 2: Business-based network led by the state-owned utility (Network 2)

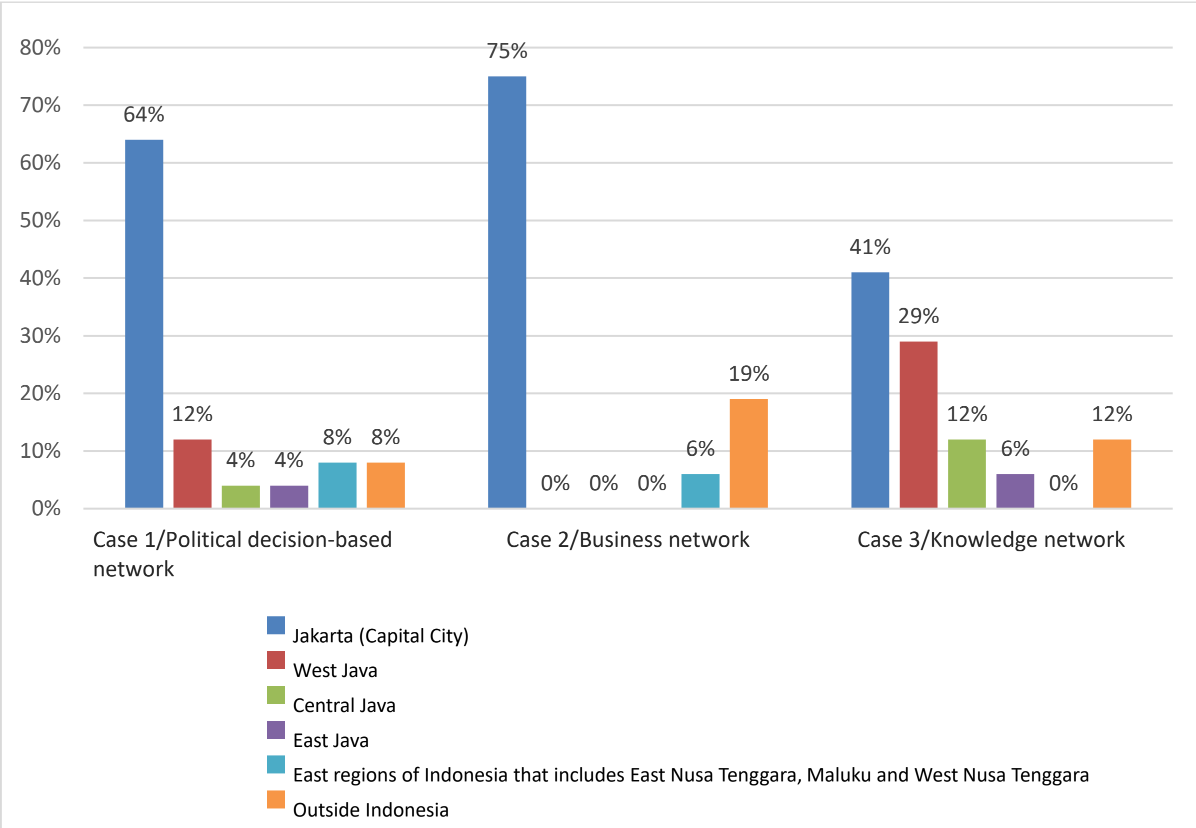
Case 3: Knowledge-oriented network led by the education policy maker (Network 3)

Source: Own depiction

Figure 4-3 Details of participants of on-line survey

Location of participants of on-line survey

In general, the majority of participants in the on-line survey were located in the capital city, Jakarta (See Figure 4-4). For example, for Case 1, more than 60% of participants were active in Jakarta,12% of participants were located in West Java and 8% of participants were in the eastern region of Indonesia as well as outside Indonesia. Meanwhile, for Case 2, besides having most of the participants from the capital city, there was also 19% of participants that were positioned outside Indonesia and 6% of participants that still handled their project in the east of Indonesia. Furthermore, participants that belonged to Case 3 were distributed in various locations, including 41% of participants from the capital city, 29% of participants from West Java, 12% of participants from Central Java, 6% of participants from East Java and 12% of participants that were located outside Indonesia.

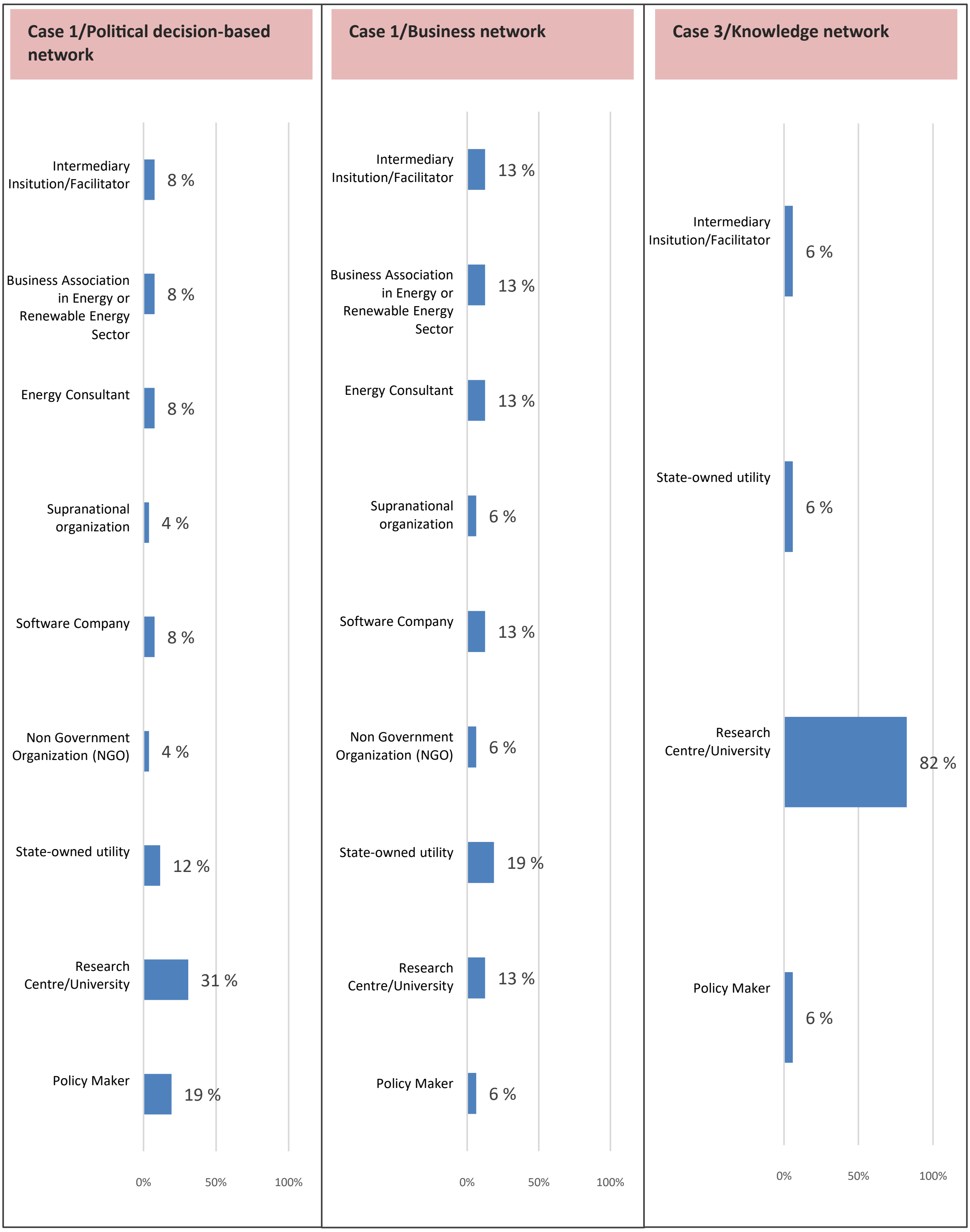


Source: Own depiction

Figure 4-4 Location distribution of on-line survey participants

Organizational background of participants of on-line survey

Figure 4-5 shows that each innovation nexus for smart grids in Indonesia potentially had different characteristics of the composition of stakeholders as depicted through participants of on-the line survey that came from multiple organizational backgrounds. Groups for Case 1 and Case 2 consisted of participants that came from various entities. In those groups, there were experts that came from facilitator organizations, business associations in the energy sector, private energy consultants, supranational organizations, software companies, NGOs, state-owned utility, universities and regulators/policy makers. One can see that participants belonging to the innovation nexus led by the energy policy maker had three types of major organizations as their origin, including the academic organization (31%), regulator/policy maker (19%), and state-owned utility (12%). Meanwhile in Case 2, beside the state-owned utility that had the highest proportion of participants (19%), the presence of other entities included software companies, academics, private energy consultants, business associations for energy, and intermediary organizations were also seeable. On the other hand, Case 3 shows a composition of participants that were mostly from academic entities (82%). There were also participants involved in Case 3 that came from facilitator organizations, state-owned utility and policy makers (each around 6%).

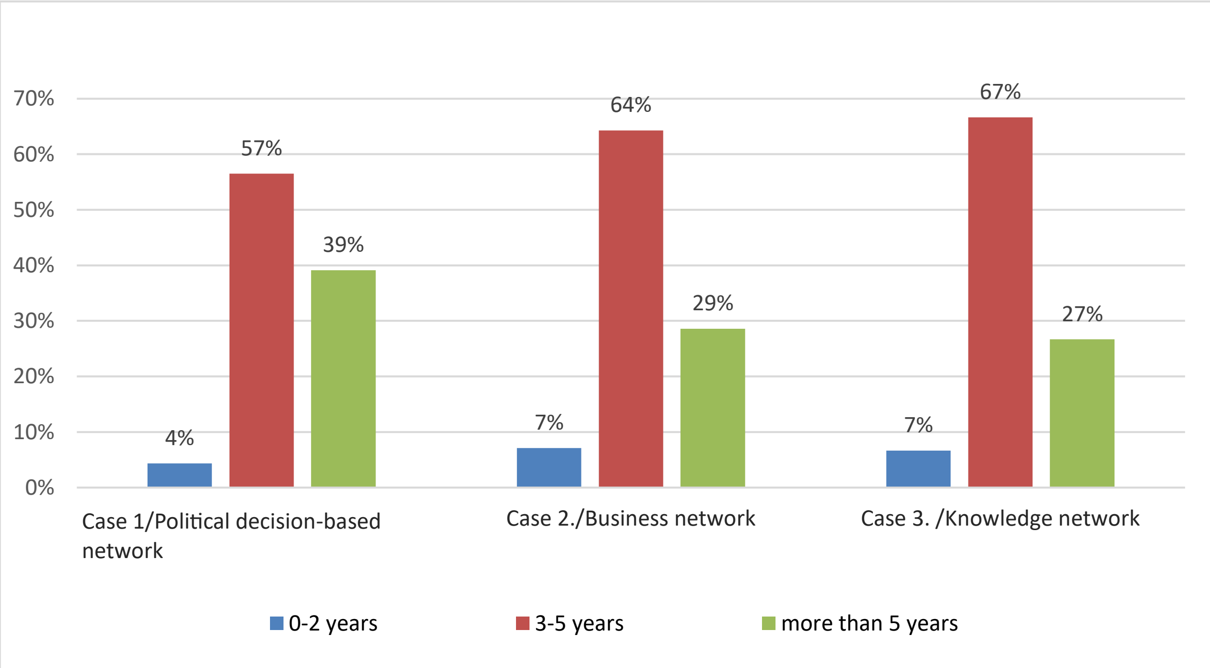


Source: Own depiction

Figure 4-5 Organizational background of on-line survey participants

Years of experience of participants of on-line survey

Based on Figure 4-6, it can be seen that more than half of the total on-line survey participants had three to five years of experience involvement in smart grid movements in Indonesia. In general, only less than 8% of total participants had conducted smart grid projects for less than two years. In addition, the average proportion of participants that had worked on smart grid related activities for more than five years was around 30%. It can also be seen that participants involved in Case 1 had more years of experience than other participants from other cases because they together had the highest proportion of experts that had experience in handling smart grid projects for more than five years. Case 1 also had the lowest proportion of experts that had experience in executing smart grid agendas for less than two years.

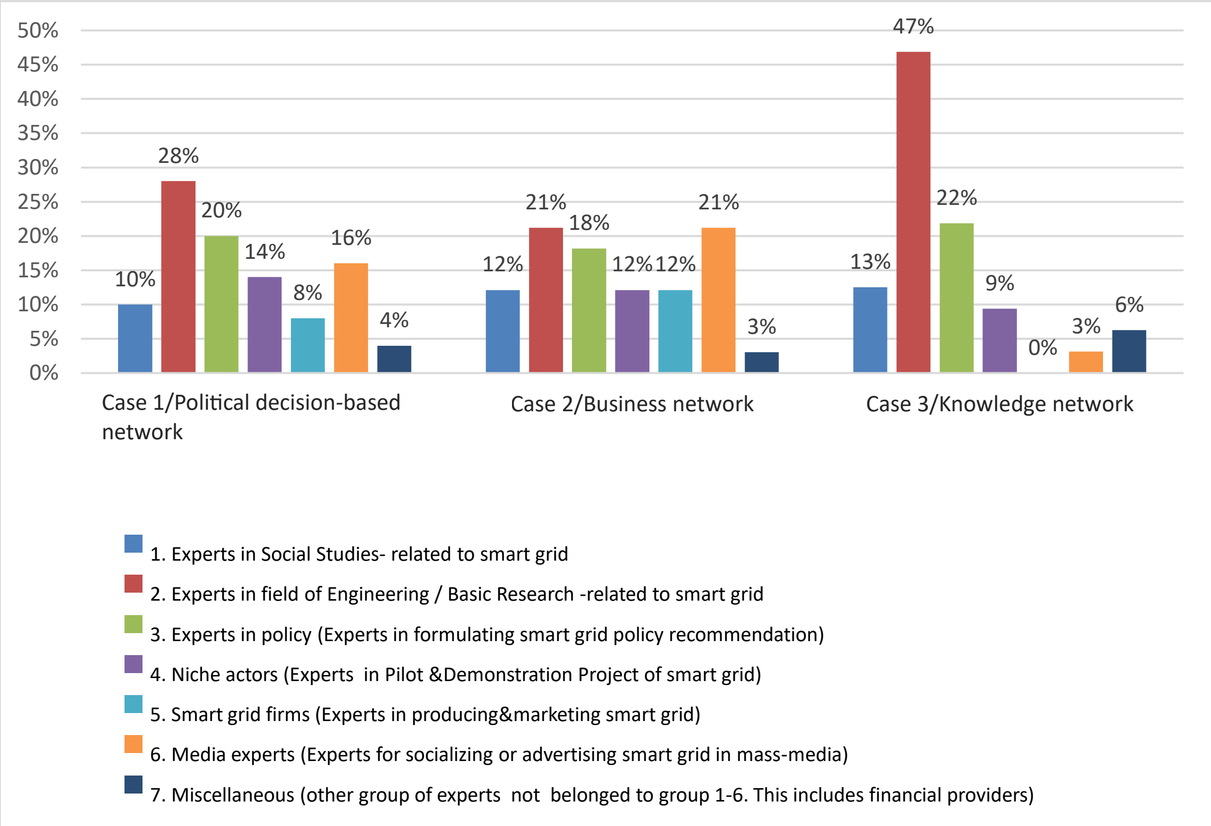


Source: Own depiction

Figure 4-6 Years of experience of on-line survey participants in handling smart grid projects in Indonesia

Range expertise of participants of on-line survey

Based on Figure 4-7, in general, engineers, policy analysts and experts in social studies came up as the most frequent competencies of the participants. In the group of participants that belonged to Case 1 and Case 2, there was a noticeable contribution from pilot project executors, smart grid companies, and media experts. Meanwhile, a cluster of participants that belonged to Case 3 was dominated by engineers. In the cluster belonging to Case 3, there were no representatives from industry. In addition, the proportion of experts of on-site demonstration projects in Case 3 was also quite small in comparison to engineers. Nevertheless, Case 3 had the largest proportion of social scientists.



Source: Own depiction

Figure 4-7 Expertise of on-line survey participants

4.4.5 Data collection through in-depth interviews

Below is the list of interviewees of the study. In-depth interviews were conducted via telephone between June and November 2019. The average duration of an interview was 44.25 minutes and interviews were conducted in Bahasa (Indonesian) due to the request of the interviewee. All in-depth interviews were documented. In addition, there were four interviews for each case study (See Table 4-4). The interviewees were selected from participants in the on-line survey based on their availability, length of experience in involvement in the particular innovation network or case, type of organizational background, knowledge about actual demonstration projects or entrepreneurial activities within their network, and number of connections with other stakeholders.

Table 4-4 List of interviewees

Number (Nr.)	Institution	Area of expertise	Expertise	Time of interview	Duration of interview
1	Indonesian state-owned utility/incumbent firm	Smart grid policy and pilot projects in Indonesia that involved the Indonesian energy policy maker and state-owned utility	Case 1	June 2019	45 minutes
2	Public research centre	Innovation policy related to smart grids and pilot Projects/R&D projects done by academics in Indonesia	Case 1	June 2019	44 minutes
3	Private energy consultant	Pilot projects (advisors)	Case 1	July 2019	42 minutes
4	Energy policy maker	Smart grid policy in Indonesia	Case 1	July 2019	45 minutes
5	Supranational Organisation	Smart grid policy and pilot projects in Indonesia that involved Indonesian energy policy maker and state-owned utility	Case 2	July 2019	44 minutes
6	Indonesian state-owned utility/incumbent firm	Policy and pilot projects conducted by state-owned utility	Case 2	July 2019	45 minutes
7	Research centre under the Indonesian state-owned	Renewable energy business and its policy in Indonesia	Case 2	November 2019	45 minutes

	utility/incumbent firm				
8	Private energy consultant	Pilot project (executor)	Case 2	November 2019	42 minutes
9	Energy policy maker	pilot project facilitated by energy policy maker	Case 3	July 2019	47 minutes
10	Public research centre	Innovation Policy related to Smart grid and Pilot Projects/R&D projects done by academics in Indonesia	Case 3	August 2019	45 minutes
11	University	Smart grid policy in Indonesia and R&D Activities done by universities and research centres	Case 3	September 2019	41 minutes
12	Private energy consultant	Pilot project (executor)	Case 3	October 2019	46 minutes

Source: Own depiction

4.5 Data processing and analysis

Data analysis of this study was based on the data gathered from the on-line survey, the integral transcription of the interviews, and data from academic documents (online-media sources, newspapers, scientific journals, books, policy /government documents, reports, brochures and any other type of written relevant documents). In addition, cross-tabulation data was made for summarizing responses from the on-line survey. Descriptive analysis was conducted to produce frequencies and percentages.

In addition, in order to analyse the degree of centrality of each network case as well as to measure the potential intervention of leading actors in their network, the research utilized social network analysis through calculation and visualisation of interrelationships between stakeholders using *Network Phyton-PyCharm software*. Social network analysis is one of the approaches for investigating the degree of influence (centrality) of each actor within a network, especially to find out how they can impact each other's behaviours through their connectedness, cohesion and clustering.

Terminology used in the analysis:

1. Node (vertex): The fundamental unit of a network (e.g. a stakeholder is the node of the stakeholders' network)
2. Edges (Links): The line connecting two nodes.
3. Degree centrality: It measures the most central and 'most important' actors of a network. Actors in a central position have greater opportunities to have a better bargaining position and more influence. Such central actors can both foster as well as hinder the effectiveness of an innovation network because they connect other stakeholders with different knowledge backgrounds as well as potentially excluding other stakeholders from gaining access to certain information.

   Degree of Centrality of a stakeholder is equal to the number of links owned by a stakeholder divided by the total potential links created within a network. In this context, the potential links are equal to the total number of stakeholders within a network multiplied by the total number of stakeholders within a network minus one.

   Degree of Centrality of Stakeholder i $= \frac{\sum Links\ Stakeholder(i)}{\sum Potentiallinks\ of\ network}$

   .... Equation 4-1

   Where: ∑Potential-Links network = (∑Stakeholders*(∑Stakeholders-1))

4. Closeness centrality: High closeness centrality reflects the ability to access information through the communication flows within the network. In innovation networks, the closeness centrality describes the strategic position of an actor within the network. If an actor with a high closeness centrality left a network, this would have severe consequences for the functioning of the overall network.

   Closeness centrality – Stakeholder i $= \frac{Geodesic\ Distance\ Stakholder\ (i)}{\sum PotentialLinks\ a\ network}$

   .... Equation 4-2

   Where: Geodesic Distance Stakeholder i = $\sum Links\ Stakeholder(i) * ((\sum PotentialLinks\ \ network - \sum Links\ Stakeholder(i)) * 2))$

5. Betweenness centrality: This measure is find out the extent to which an actor lies ‘‘between’’ all the other actors in the network or, in other words, the percentage of times an actor lies on the shortest path ‘between’ two other actors. Actors that lie on many shortest paths between other parties have a higher value of betweenness centrality compared to others. An actor would be more powerful and influential, if there are more indirect ties to other actors that are mediated and controlled by him/her.

Betweenness Centrality Stakeholder i= $\frac{2*\ (Potential\ of\ Stakeholder\ i\ to\ act\ as\ intermediaries)}{\Sigma\ Potential\ links\ a\ network\ ((3*\Sigma\ number\ of\ Stakeholders)+2)}$

.... Equation 4-3

Where: Potential of Stakeholder i to act as intermediaries= capability of stakeholder i in creating different collaborations which involving two other stakeholders.

C(n, r) = n!/(r! (n –r!)

.... Equation 4-4

Where:

C: Potential of Stakeholder i to act as intermediaries

n: $\sum Links(i)$

r=2

4.6 Validity and reliability

The validity of research refers to the suitability or accurateness of methods in comparison to the topic or aims of the research. Meanwhile, reliability is defined as the quality and consistency of the method to achieve the results (Yaghmaie 2003; Ospina 2004). In this study, several methods were utilized to ensure that the validity and reliability of the research’s results were achieved. Those include a review of experts, pre-testing of the data collection instruments, and triangulation.

Review of experts

According to Taherdoost (2016) and Bannigan and Watson (2009), the judgment of experts can be applied to test the validity of data collection instruments. The experts were asked for their opinion about the data collection instrument and how the researcher can improve those instruments to improve the validity of the results. In this study, experts were requested to review the questionnaire as well as the interview schedule. The experts included two from the University of Oldenburg, two from the section of energy management and renewable energy laboratory of the *Technische Hochschule Aschaffenburg*, one from a private energy consultant in Indonesia, and one from an international NGO that implemented projects related to smart grid with ASEAN and the Indonesian state-owned utility. Those experts provided feedback that was then incorporated in to the data collection instruments before they were used in the field. The most common feedbacks included the need of easy explanation about several concepts related to smart grids, the ability of the questionnaire to cover elements analysed in the study, and time needed to answer the questionnaire or to complete an interview.

Use of tested questions

According to Ndaki (2014) and Dawadi et al. (2021), the validity and reliability of data can be enhanced through utilizing tested questions or data collected instruments. In line with this, many questions designed in the research were mainly inspired by literature. The literature provided examples of questions for informants related to the topic of this study. Since the number of literature reviews that solely examine innovation networks as indicators of formation and development of a technological innovation system (TIS) is still limited, the questions for informants were collected from several different topics of studies that included resource network orchestration, management of innovation network, opinion leaders and innovation networks, TIS functions, and niche management. Examples of those literature reviews used include: (Gretzinger et al. 2010; Howells 2006; Cantner and Graf 2006; Bittencourt et al. 2021; Batterink et al. 2010; Musiolik 2012; Nilsson and Sia-Ljungström 2013; Siegel and Strong 2011; Geels 2014; Pushpananthan 2022; Suurs 2009; Aksenova 2020; Rampersad 2008; Bergek et al. 2010).

Pre-testing the instruments

Pre-testing of instruments is very useful to identify and manage potential shortcomings of the data collection instruments before beginning data collection in the field (Creswell 2014). This method enables the researcher to refine their data collection instruments so that the generated data is optimal and reflects the context of the study, hence validity and reliability of the research findings are ensured (Busetto et al. 2020; Hammarberg et al. 2016). For this study, the pre-testing of the questionnaire was done in mid October 2018. The two experts from the PJCI were successfully contacted through snow-ball sampling method to be asked to complete the on-line questionnaire. Based on that, the multiple-choice questions with details of organizational backgrounds of on-line survey participants was added to the questionnaires. Questions about the mode of initiation of collaborative arrangements in the questionnaire was also replaced with questions about goal, initiator, and characteristics of common resource utilization of collaborative arrangement. In addition, pilot in-depth interviews were also conducted in early March 2019 with two key contacts from PJCI. The results showed that an interview guide was needed to aid translation into Bahasa Indonesia in order to get accurate and deeper answers from the interviewee.

Triangulation

Triangulation refers to the utilization of multiple data collection methods and analysis in order to enhance the validity of findings and to understand more the situation of the object of the study in different ways (Alnaim 2015; Zach 2006; Doyle et al. 2016). Related to this, the research presented both methodological and data triangulation through the application of a mixed method approach that consists of both quantitative and qualitative phases. In addition, a multiple case studies approach was also deployed in this research in order to be able to enhance the accuracy of generated data as well as the comparable findings.

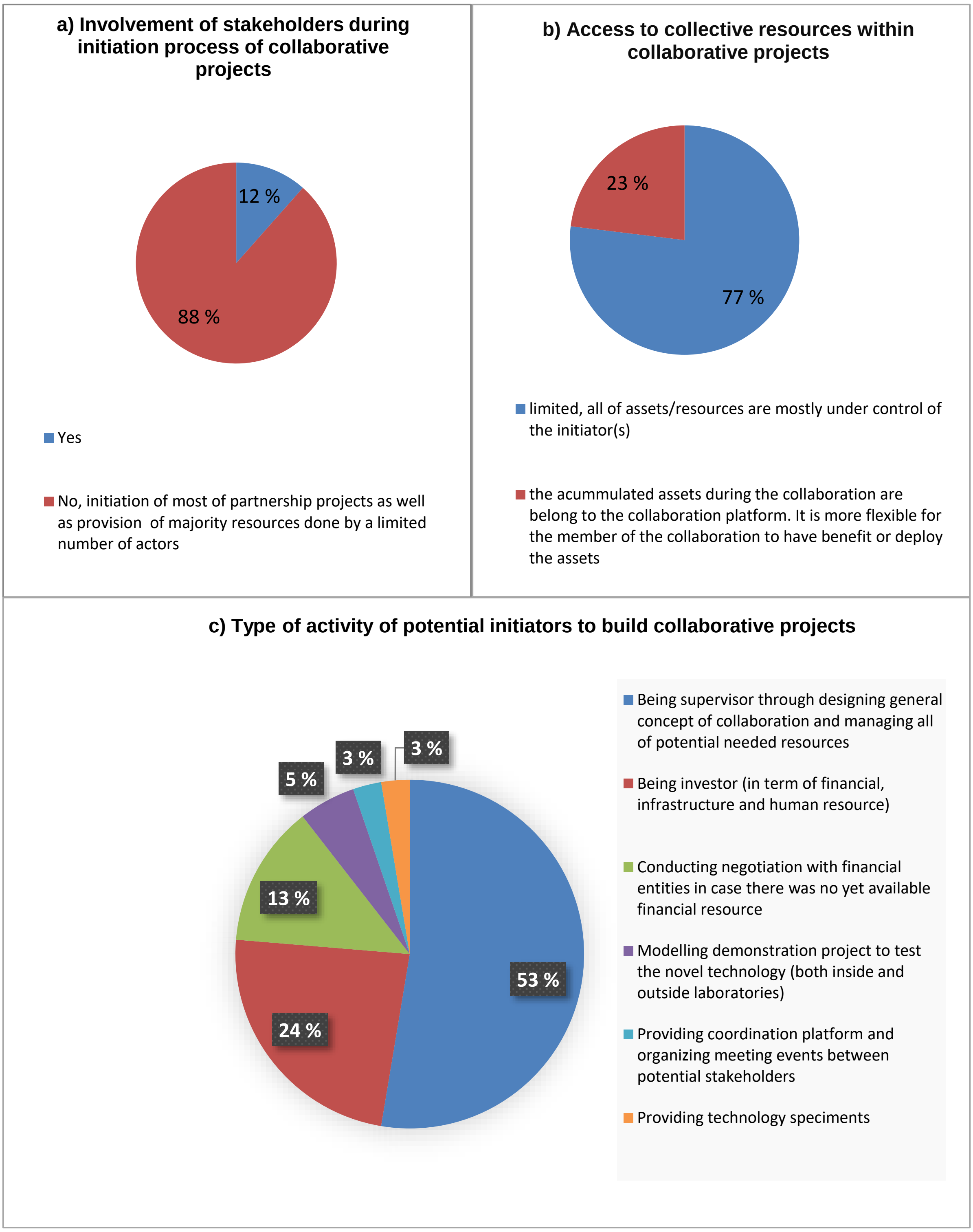
5 Case 1: The Innovation network for smart grid technologies in Indonesia facilitated by the energy policy maker (The Network 1)

This chapter describes thoroughly the dynamic of an informal innovation network for smart grid movements in Indonesia that was facilitated by the Indonesian energy policy maker from 2009 to 2019. The analysis covers several aspects, including resource management of the network in general, the intervention of leading actors in influencing members of the network and the performance of the network in implementing the functions of system of innovation.

5.1 Dominant network resource orchestration undertaken by a limited number of stakeholders

The mode of initiation of collaborations and characteristics of resource deployment are among indicators to describe the characteristics of project management undertaken within an innovation network. Findings based on the on-line survey show that almost 90% of total collaborative projects within Network 1 was generated by a limited number of stakeholders (See Figure 5-1). Subsequently, stakeholders argued that the majority were not allowed to utilize the accumulated resources or outcomes generated from their partnership in a flexible way. They explained that the management of assets and products under collaborative projects was mainly controlled by the initiators.

Meanwhile around 12% of stakeholders were implicitely argued to be categorized as potential creators of collaborative projects (See Figure 5-1). According to them, multiple initiators that consisted of supervisors and co-initiators mostly existed in the majority of projects, because it was very challenging to supply all of the materials required for those projects individually. Different activities were done by those potential initiators in order to build partnership projects within the Network 1 (See Figure 5-1). More than half of those builders formed their co-operation by designing the general concept of their project and sent them to their potential partners. In addition, 23% of potential projects initiators acted as resource providers during the formation process of partnership projects. Furthermore, 13% of potential collaborative builders conducted active negotiation with potential financiers as a starting point to realize their projects. Other findings included potential project creators that initiated cooperation projects within Network 1 through modelling demonstration projects (5%), providing meeting platforms for potential partners (3%), and proposing technology prototype (3%).



Source: Own Depiction

Figure 5-1 Characteristics of resource orchestration applied in collaboration projects within network 1 (2009-2019)

Based on an explanation from expert- informants, the initiation of collaborative projects within Network 1 was mainly under programs or agendas that were issued by the energy policy maker and utility. In addition, it is reported that some of the projects were proposed by smart grid innovators. Those firms had an eagerness to implement their projects within the nexus belonging to the energy policy maker because it may benefit them. The policy maker had a type of reputation or legitimacy that enabled a broad range of involved stakeholders to join their project or to pay attention. In addition, a small number of projects were proposed by academics under the wings of the energy policy maker, mainly due to possibilities in gaining resources owned by the nexus.

''I think projects that were within the circle of the energy policy maker were mostly created or proposed by the energy policy maker itself and the state-owned utility. In addition, I saw that smart grid companies also proposed their projects within the nexus because it was beneficial (for them). The energy policy maker and its nexus eased (their) projects through their beneficial political legitimacy and prestige." (Interviewee Nr. 1).

''Based on what I saw, the policy maker and the utility were the main creators (and controllers) for most activities under project related to smart grid and decentralization of power system in rural areas (the main goal of Network 1) due to their economic and political capabilities." (Interviewee Nr. 2).

''The smart grid companies and universities, specifically public research organizations, also tried to build their own collaborative plaftorms for research and demonstration project within supervision of the energy policy maker due to opportunities of access of funding and existing network belonged to the energy policy maker." (Interviewee Nr. 3).

In addition, regarding the resource management of collaboration plaftorms within Network 1, the expert-informants argued that each project had its own characteristic of how involved stakeholders utilized their accumulated resources or project outcomes. They asserted that each project had its own 'rule of the game' towards its resource management. Nevertheless, initiators were usually able to dominate the process of implementation of a project.

''Before starting to join or to execute projects, usually there were negotiations about copy rights or protocols in utilizing resources as well as claiming the outcome of the projects. Nevetheless, the initiators dominated the process because the ideas and resources used in the projects were, in the majority, belonging to them." (Interviewee Nr. 4).

''Based on my experience, research projects or on-site pilot projects that were under the supervision of the energy policy maker had exact rules when involved actors wanted to utilize the resources or outcomes derived from the projects. In those rules, involved stakeholders consisted of initiators of projects and professionals invited by the initiators of the projects (more than 80% of total stakeholders), had different level of access in claiming or deploying the assets of projects (compared to initiators). Of course, initiators usually had a better access to claim the accumulated assets during the projects or outcomes of projects." (Interviewee Nr. 2).

''Of course there were rules in deploying assets or resources that most of them belonged to initiators. Not all information about projects can be shared or accessed by people outside projects without licenses or permits from the initiators." (Interviewee Nr. 1).

''Except for seminars, where collected information from these activities were allowed to be shared to a broad range of stakeholders, the outcomes from research projects or prototype testings in certain locations was not allowed to be shared or utilized freely by the involved stakeholders without communication with initiators." (Interviewee Nr. 3).

5.2 Intervention of the energy regulator towards its innovation network

5.2.1 Potential influence of the energy regulator upon its own network was overshadowed by the incumbent firm

Figure 5-2 represents the average value of social network indices, including the degree of centrality, closeness centrality and betweenness centrality of each stakeholder (type of organization), in Network 1. According to the theory, the highest value of social network indices is one and the lowest value of social network indices is zero. Meanwhile, in Network 1 the average score of the closeness centrality of all stakeholders (0.32) was greater than the average score of degree centrality (0.26) and the average score of betweenness centrality (0.21). Those numbers indicate that the performance of the stakeholders in Network 1 was quite low on average, based on its the capacity to efficiently share information, to encourage collaboration among stakeholders, to act as a unit or to be centralized as one entity. In addition, it seemed that the activities involved in circulating information within the network was easier than encouraging all the stakeholders to engage in partnership projects. To be integrated in one cooperation platform was a quite difficult task for most stakeholders. Because of this, the ties between stakeholders may often be weak and could break more easily. The circulated information among them were conceivably rather redundant.

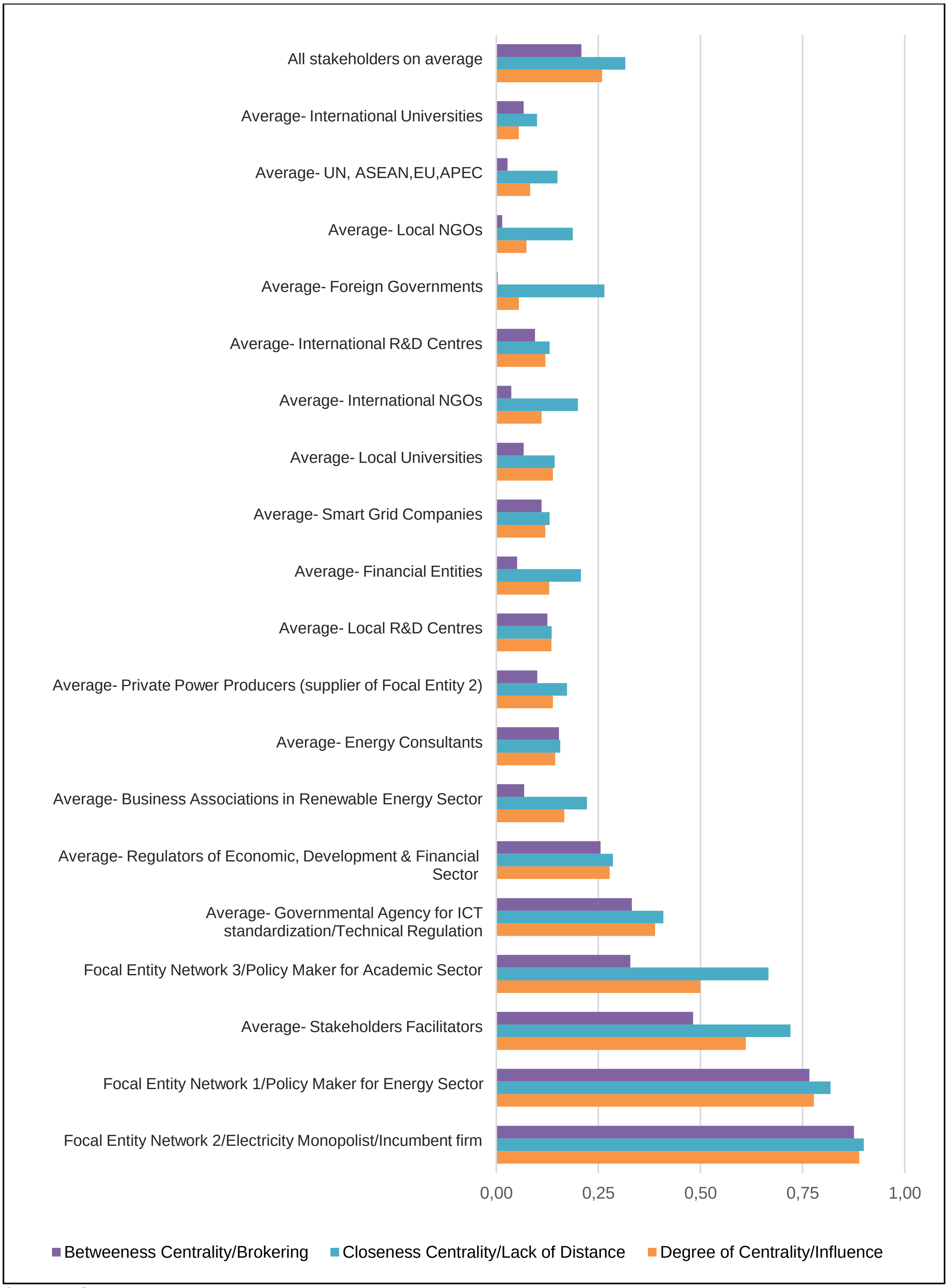
In addition, the result shows that even though the network was somehow informally created by the energy policy maker, the state-owned utility showed its potential to be the one on the top who could prominently administrate Network 1, with an average value of social network index of 0.88. It not only had a high value of degree centrality (0.90), but also a high value of closeness centrality (0.89), and betweenness centrality (0.88). It means that the electricity monopolist/incumbent firm in Indonesia had a strong possibility to influence the network through implementing policies, circulating information, and intervening with other stakeholders in engaging a cooperation. Meanwhile, the energy regulator positioned themselves as the second potential regulator of Network 1. It owned an average value of social network index of 0.78. It could be seen that it had a strong capacity to deliver information within the network (closeness centrality index=0.82), to integrate or disintegrate the network (degree of centrality =0.77), and to encourage or discourage cooperation between other stakeholders (betweenness centrality=0.77).

The possibility of the utility as well as the energy regulator to work side by side in controlling the network was also mentioned by expert-informants. They asserted that the energy regulator was indeed influential in creating projects and funding opportunities, however, at the level of implementation, the energy regulator would likely have a high dependency on the utility/incumbent firm. The company not only had offices in all regions of Indonesia, but also a wide network of communication with academics as well as the capacity to mobilize local operators or undertake consolidation with local government.

''The ministry for energy had the ability only to issue programs to encourage many collaborations (which was firstly should be already agreed by the policy maker for finance and national development planning). However, it had a limited number of instruments to control the implementation of its programs or to involve (directly) in the main location of the projects.'' (Interviewee Nr. 3).

''The Incumbent firm had the influence and the capability to mobilize the local actors (this included local governments and important local leaders), since all the electricity system (its operation) was controlled by him.'' (Interviewee Nr. 4).

Furthermore, in Network 1, there were stakeholder facilitators and research and higher education policy makers which had a rather low similary, either to enhance cooperation or to control movement among stakeholders, yet they did have a high possibility to provide communication channels for all stakeholders. The value of the closeness centrality index for those entities was 0.72 and 0.69 respectively. Another essential feature shown in Figure 5-2 is that the average social network indices for local research centers and universities was very low. It reached a point of 0.14 and 0.12 respectively. It depicted a situation where the opportunity as a single academic entity to control the network was small.



Source: Own Depiction

Figure 5-2 Different value of social network indices between different groups of stakeholders of Network 1 (2009-2019)

5.2.2 Actual Intervention of the energy policy maker in its Innovation network : Between building and hindering

5.2.2.1 Building up the network

Initiating more than one third of partnership platforms in its network

Based on the result of the on-line survey, between 2009 and 2019 the energy regulator proved its role as the biggest creator of collaboration arrangements within Network 1. It successfully contributed to the production of 35% of total co-operation projects. The action was followed by the utility generating 22% of total co-operation projects. Interestingly, the smart grid companies also came up as the significant builder of partnerships among members of Network 1 by initiating 14% of total projects. Meanwhile, universities and research centres contributed to the formation of 11% total projects. Other entities, such as stakeholder facilitators and supra national organizations, initiated around 3%-5% of total projects.

Influencing the network through giving guidance

Between 2008 and 2019 the energy policy maker periodically produced several long-term pieces of guidance for stakeholders in the electricity sector in Indonesia, the so-called National Electricity Plan (*Rencana Umum Kelistrikan Nasional/RUKN*). The documents explicitly mentioned the importance of modern technology that could enhance a more reliable and efficient electricity system based on renewable energy in Indonesia. The list of the plans was as follows:

- National Electricity Plan (*Rencana Umum Ketenagalistrikan Nasional/RUKN*) 2008-2018: The document provided stakeholders with the actual condition of renewable energy, the opportunities and the challenges in Indonesia. It also introduced the latest innovation related to renewable energy technology, for example smart and efficient hybrid power systems.
- National Electricity Plan (*Rencana Umum Ketenagalistrikan Nasional/RUKN*) 2013-2027: The plan explained a strategy to enhance renewable energy deployment as well as electrification ratio in poor, rural and remote regions in Indonesia. Renewable energy integration through a smart system was mentioned as one of the important innovations that should be deployed and developed.
- National Electricity Plan (*Rencana Umum Ketenagalistrikan Nasional/RUKN*) 2015-2034: The document introduced the relevance of the feed in tariff mechanism to enhance renewable energy deployment in Indonesia. Smart battery systems and smart grids for more reliable electricity, transmission and distribution were mentioned as important innovations. Furthermore, smart systems for hybrid renewable energy systems in rural areas were also recommended to be more developed.

- National Electricity Plan (*Rencana Umum Ketenagalistrikan Nasional/RUKN*) 2018-2037: The guidance introduced the importance of a decentralized power system and two-way communication between electricity producers and consumers. The paper also recommended stakeholders to develop their innovation to enhance the efficiency of transmission and distribution of the conventional power system in Java-Bali Island.
- National Electricity Plan *(Rencana Umum Ketenagalistrikan Nasional/RUKN*) 2019-2038. The Guidance recommended some topics for innovation activities in Indonesia, including demand side management, supply side management, smart building/smart house, smart street lightening, smart vehicle, smart microgrid for rural areas and smart battery systems.

Aside from the National Electricity Plan, the energy regulator also issued the regulation of MEMR No. 24/2015 regarding national planning of the electricity system (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2015b). It was the goal of the government of Indonesia to cover 23% of its electricity demand from renewable energy resources in 2025 and then 31% in 2050. According to the regulation, the key to achieve the target was Indonesia enhancing its innovation, especially by developing and deploying smart technologies that could handle intermittent issues, reliability issues, renewable energy – and its smart automation and smart battery system.

Deploying incentives

In 2012, the energy regulator issued the Regulation of MEMR no. 14/2012 about energy management (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2012b). The regulation encouraged energy users, especially for government bodies, to deploy a better energy management. In article 3 of the regulation, it stated that the government encouraged modern applications that could ease the energy automation process, enhance co-generation or hybrid power production applications and provide a more efficient electricity system and its maintenance. Public private partnerships supported by local government to enhance successful energy management were recommended in the regulation. Furthermore, in 2017, the energy regulator released the Regulation of MEMR no. 27/2017 concerning service transparency of quality and price of electricity in Indonesia (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2017b). It opened the possibility of two-way communication between energy producers and consumers by using an up-date technology, for example smart meter applications.

5.2.2.2 The energy policy maker, together with the state-owned utility, tended to hinder its own innovation network

Whilst developing its network through various agendas, the energy regulator took actions that were significantly counter productive. Several decisions made by the energy regulator had either a direct or indirect potential negative impact on not only the members of Network 1 but also various actors that were involved in other networks of smart grid movements in Indonesia, especially a network that was led by the state-owned utility.

In the beginning of 2017, the policy maker for energy released the Regulation of MEMR no. 50/2017 which was about the cancellation of the feed in tariff (FIT) for electricity generation based on renewable energy resources and the introduction of a ceiling price system (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2017c). There was a difference in standard operating costs of power system between regions in Indonesia. In this system, the state-owned utility also acted as both monopolist and oligopolist in the national electricity sector, including acting as owner of all national electricity transmission and distribution. According to the ceiling price system, if power generation in a certain region had standard operation costs that were higher than the standard national operation costs, then the selling price of the generation to the grid would be equal to the standard national operation costs. On the other hand, if the costs were lower than the standard national operation costs, then the selling price to the grid of the generation would be as much as 85% of the standard national operation costs. There were pros and cons related to the regulation. Many investors developing renewable energy projects in and outside Java and Bali Islands who had costs that were much higher than the standard national operation costs, were dissatisfied. Because they received a lower selling price due to the regulation, they made their pay back period of their investment longer (Hamdi 2019; Lontoh et al. 2016). Apart from that, in 2018, the energy regulator added a measure through Regulation of MEMR no. 38/2018 (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2018b). The regulation stated that a power generator could sell its production to the electricity monopolist if it had fulfilled all of the qualifications required by the electricity monopolist and had won the procurement process organized by the electricity monopolist. In other words, not all renewable energy generations were able to automatically sell their electricity to the grid. The regulation hindered most of the potential investments for renewable energy projects.

Regarding financial aspects, the energy regulator declared a measure for PV-Rooftop Prosumers based on Regulation of MEMR no. 49/2018 (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2018c). The action was aimed at cancelling the decision of the director of the utility/electricity monopolist No.0357.K/DIR/2014 which provided a ratio of 1:1 to export the import price of excess electricity from and to the grid for private prosumers. The energy regulator then reduced the ratio of the export price; thus, the actual ratio of the export/import price became 0.65:1. In addition, prosumers should cover tax and operational costs as well. In the following year, there was also the Regulation of MEMR no. 16/2019 which stated that prosumers should pay the capacity charge beside the operational costs on a monthly basis, where, the capacity charge= Inverter capacity *5 hours* electricity tariff (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2019d).

Still related to the prosumers, the energy regulator cancelled the Regulation of MEMR no 01/2017 and replaced it with the Regulation of MEMR no. 13/2019 (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2019c). The Regulation of MEMR no 01/2017 granted the opportunity to give a legitimacy for renewable energy prosumers, most of them households with photovoltaic system, to be connected to the grid and to officially undertake import and export of electricity from the grid. It gave authority to the utility to give or to reject every application from a citizen to be a prosumer. Through the Regulation of MEMR no. 13/2019 about PV Prosumers, the potential PV prosumers could only operate their system if they were granted licenses from local government, the utility as well as from the directorate general of renewable energy under supervision of the energy regulator. The condition conceivably delayed many potential prosumers from using the technology, since it took a significant amount of time to deal with the administration process while applying the licenses.

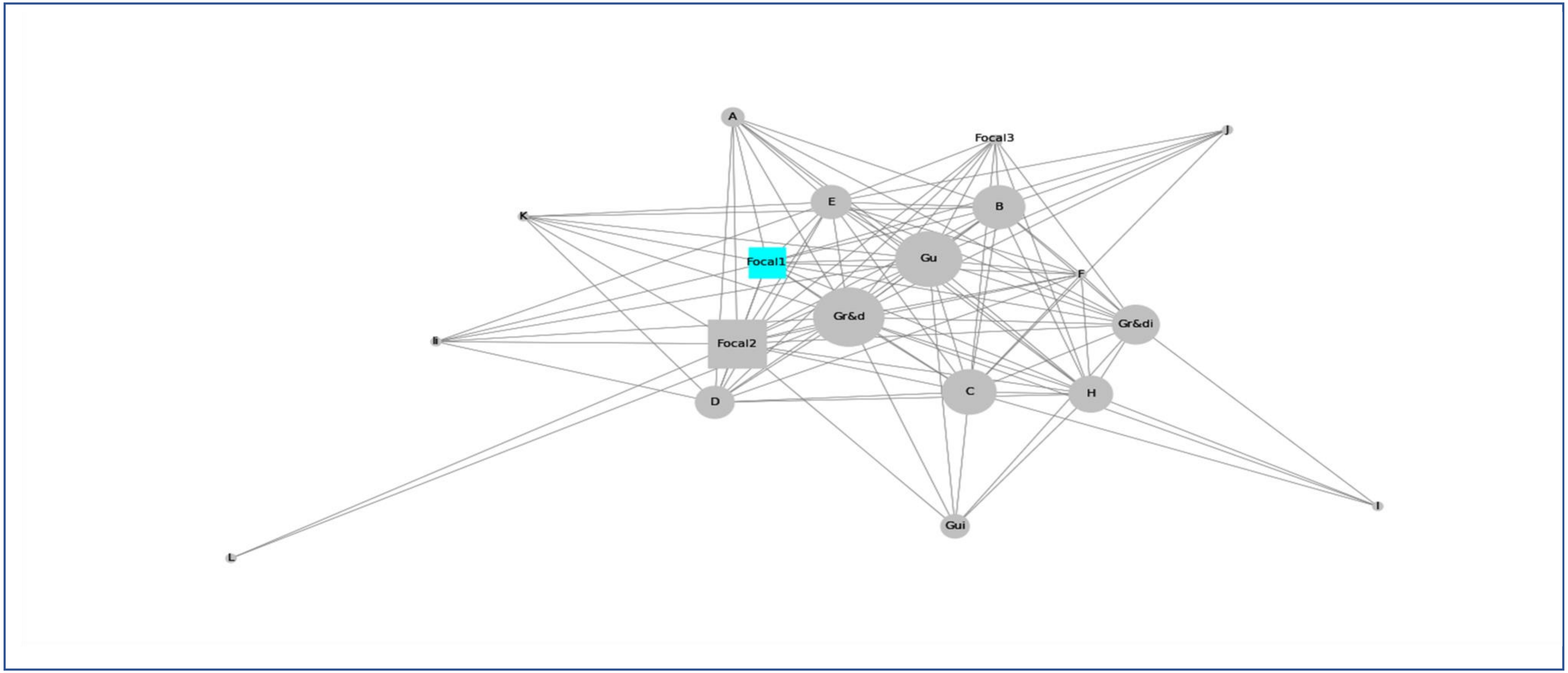
5.3 Performance of the network in implementing the functions of the technological innovation system (TIS) of smart grid technologies: The policy maker was in the office, the incumbent firm and academics were in the field

5.3.1 Performance at a macro level through collective -collaborative actions

5.3.1.1 Experts from the incumbent firm and local academic organizations that dominated the network

Between 2009 and 2019, there were 19 organizational categories that were involved in Network 1. The result based on the on-line survey shows that due to the number of the connections that stakeholders had within the nexus, there were five types of organizations that acted as significant actors in the innovation network for Case 1. Those organizations included local research centres, local universities, energy consultants, the policy makers for financial & economic planning, the state-owned utility/monopolist and the policy maker for energy (See Figure 5-3). All organizations within the network had a direct link with all those five main players, excepted for local NGOs, supra national organizations (UN, ASEAN), international research centres, and foreign governments.

Furthermore, based on the distribution of the organizational background of expert-participants of the on-line survey, Figure 5-3 shows that each type of organization contributed to the number of human resources or involved players differently and created different sizes of each type of organization. The size of the state-owned utility, local research centres and local universities were bigger than other organizations. Other types of entities that also had a significant size were international R&D and research institutes, governmental organizations for technical regulation and the energy policy maker.



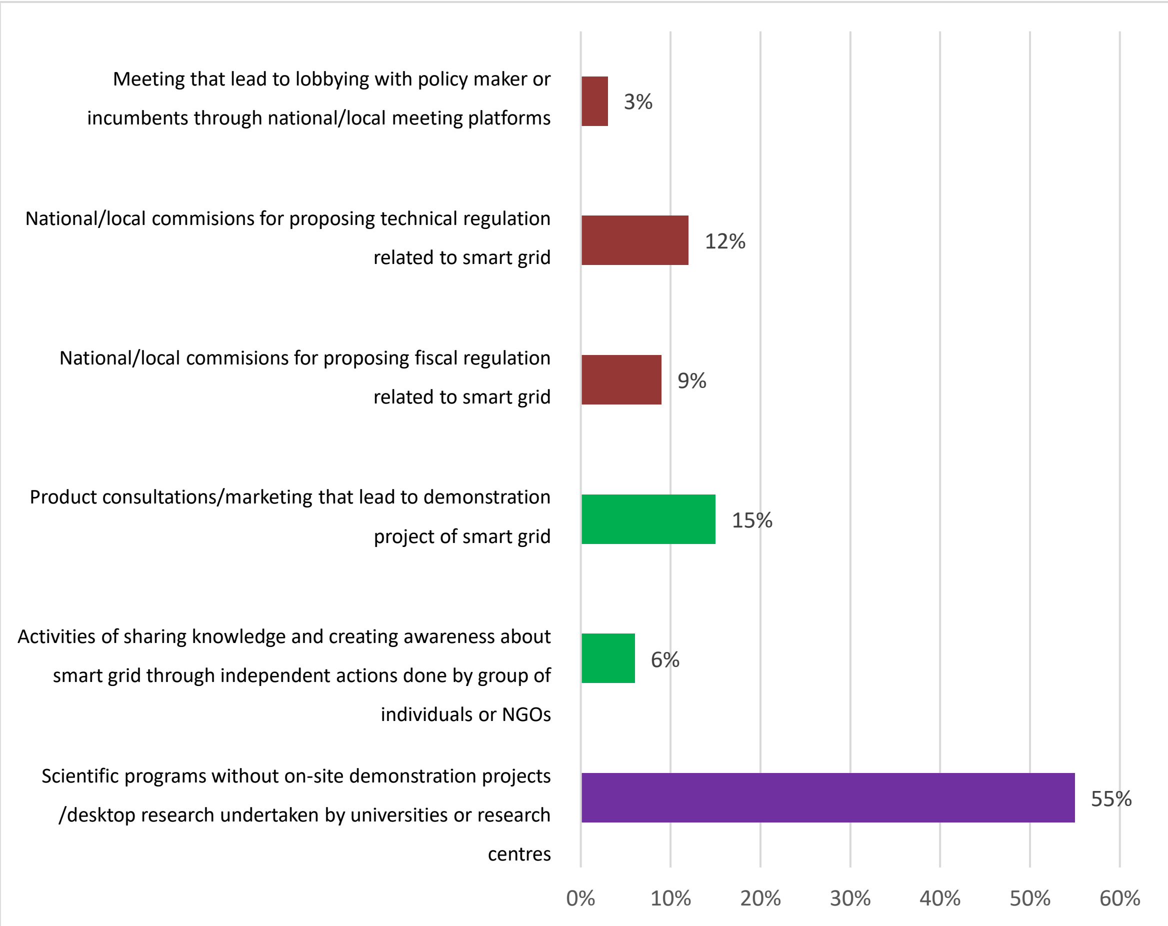
Code	Description		Code	Description		Code	Description		Code	Description
A	Business Association in Renewable Energy Sector		**F**	Private Power Producers (supplier of Focal Entity Network 2/Monopolist)		**H**	Smart Grid Companies		**K**	Financial Entities
B	Energy Consultants		**Gu**	Local Universities		**I**	Local NGOs		**L**	Foreign Governments
C	Governmental Agencies for ICT standardization/Technical Regulation		**Gr&d**	Local R&D Centres		**Ii**	Int' NGOs		**Focal 1**	Focal Entity Network 1/Policy Maker for Energy Sector
D	Stakeholders Facilitators		**Gui**	Int' Universities		**J**	UN, ASEAN,EU,APEC		**Focal 2**	Focal Entity Network 2/Utility-Monopolist
E	Regulators of Economic, Development & Financial Sector		**Gr&di**	Int' R&D Centres					**Focal 3**	Focal Entity Network 3/Policy Maker for Education/R&D

Source: Own Depiction

Figure 5-3 Feature of connectedness among different groups of stakeholders within network 1 (2009-2019)

5.3.1.2 More than half of total collaborative projects dedicated to academic domain

According to the on-line survey, Network 1 concentrated more than half of its collaborative movements in the academic domain with knowledge sharing and basic R&D programs on campus (See Figure 5-4). Meanwhile, partnerships that worked at a regime level contributed to around 24% of total projects, including national/regional committees to propose fiscal regulation (9%), national/regional committes to propose technical regulation (12%), and meetings led for lobbying through national/regional particular meeting plaftorms (3%). In addition to that, the network also engaged in activities at a grass-roots level collectively. Those activities contributed to around 21% of total projects, which included product consultations led to demonstrate projects and involved a high possibility of direct contact between smart grid companies and end-users (15%) and actions of groups of individuals in introducing smart grid technologies within the network (6%).



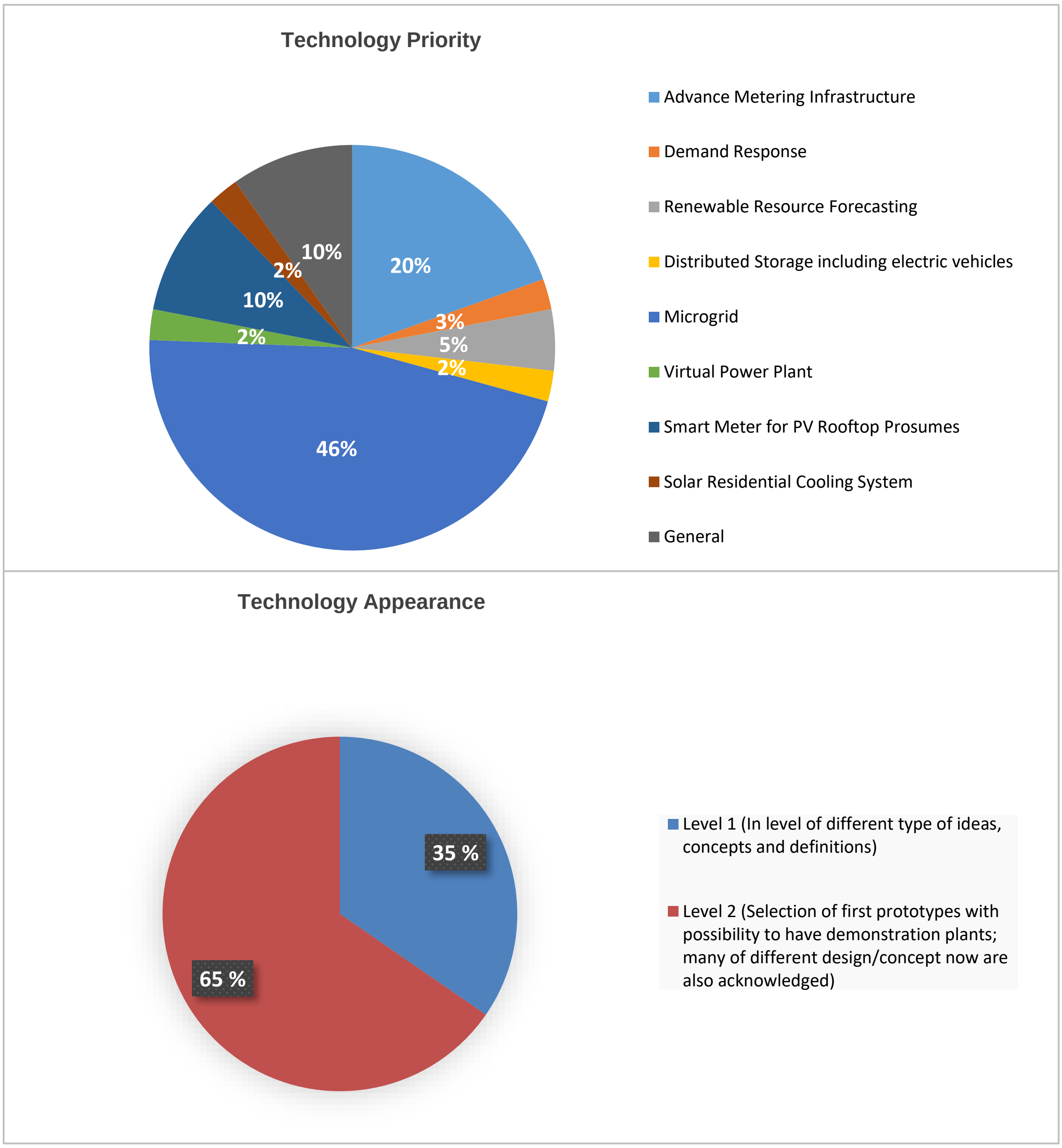
Source: Own Depiction

Figure 5-4 Collective activities to implement functions of a TIS within Network 1 (2009-2019)

5.3.1.3 Half of projects handled specimens of smart grid technologies that related to the decentralization of power generation

Based on results from the on-line survey, Figure 5-5 shows that more than half of collaborative projects within Network 1 focused on smart grid applications for decentralized power generation, including smart microgrids (46%), renewable energy forecasting (5%), and virtual power plants (2%). Meanwhile, applications for residential users also became a significant topic within Network 1. For example, Smart Meter Infrastructure (AMI) (20%), demand response (3%), distributed storage including electric vehicle (2%), smart meter PV prosumers (10%) and solar residential cooling systems (2%). In addition to that, there was 10% of total collaborative projects that was dedicated to all types of smart grid technologies in general.

Regarding technology, 65% of collaborative projects were handling prototypes of smart grid technologies that had the potential for early adoption or to be tested in local environments in Indonesia. The rest (35%) of smart grid technologies that were addresseed within the Network 1 were in the form of ideas, concepts and definitions. These results are in line with the type of activities of Network 1 in general, where the collaboration platforms were aimed at exploring and testing the potential benefit of technology in a local context as well as sharing knowledge about the most up-to-date development related to the novel technology.



Source: Own Depiction

Figure 5-5 Technology priority and technology appearance in collaboration platforms within network 1 (2009-2019)

5.3.2 Performance at a micro level through entrepreneurial experimentations: Case of Sumba smart microgrid project

5.3.2.1 Background and specification of Sumba smart microgrid

Sumba smart microgrid project was one of the on-site pilot projects for smart grids that was inspired by the energy policy maker. The project was under the umbrella of the Sumba Iconic Island program and launched in 2010 by the regulator. The program itself had a goal to achieve 100% electricity based on renewable energy in Sumba Island by 2025 (Prastawa et al. 2013).

The Sumba Iconic Island program was announced by the energy policy maker on 1 November 2010 (Castlerock Consulting 2014). It was firstly proposed by the HIVOS (*Humanistisch Instituut voor Ontwikkelingssamenwerking)* and other existing organizations which were already undertaking their projects on Sumba Island, including Winrock International, IBEKA (*Institute Bisnis Ekonomi dan Kerakyatan*) and KEMA DNV (van der Veen 2011). The negotiation to create the program was conducted in early 2009 (Akhmad et al. 2017). From the perspective of those organizations, the program was a solution for them, because they were looking for legitimacy as well as facilitation from the energy policy maker in order to gain both local and international support. The energy policy maker was seen as the only institution which had the political power as well as the validity to open negotiations and cooperation between parties, for example between on-site renewable energy project actors and local stakeholders, including local communities, the local government of Sumba Island, and the national electricity monopolist. The energy regulator may also have possibilities to provide funding opportunities for those actors, either as a financier or as a facilitator between actors and financial entities.

Sumba Island in in the east of Indonesia and belongs to East Nusa Tenggara province. It has an area of 11,153 km² and the population was 685,189 in 2000 and 781,093 in 2017 (Badan Pusat Statistik - Provinsi Nusa Tenggara Timur (BPS-NTT) 2018). The electrification ratio on Sumba Island was 24.5 % in 2010 , where 85% of electricity of the Island's electricity was produced from diesel generators (Perusahaan Listrik Negara (PLN) 2018). On the other hand, the island had the potential to adopt renewable energy such as hydropower, solar power and wind power (Prastawa et al. 2017). The Island was divided by five regencies, including Southwest Sumba, West Sumba, Central Sumba, and East Sumba. Grid infrastructure was mainly found in Southwest Sumba and West Sumba. Only a small part of Central Sumba had access to the grid. In addition, there was also national grid access along the coastal area of East Sumba.

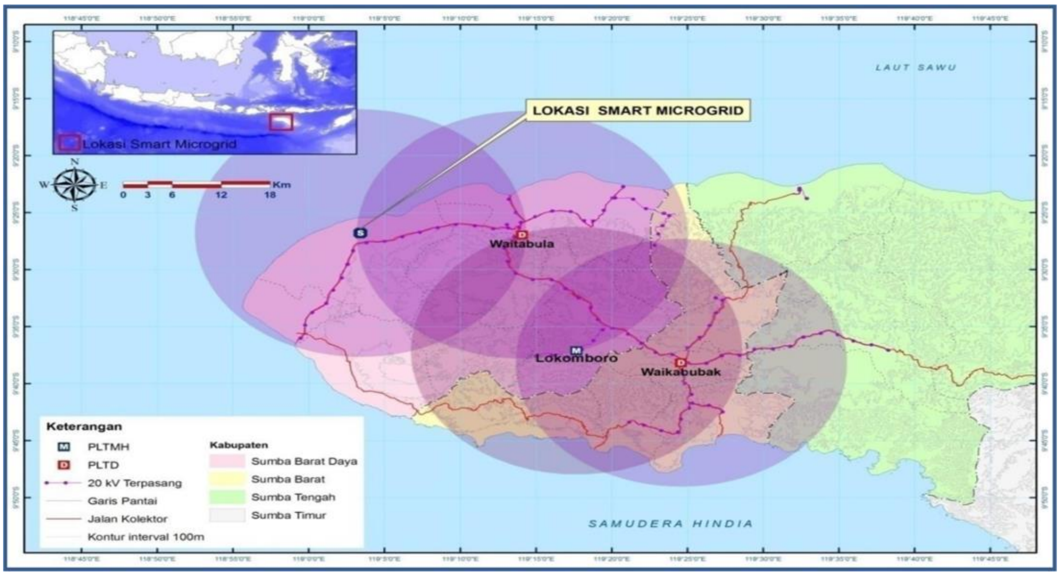
The Sumba smart microgrid project was formally started in 2012 (Prastawa et al. 2013). The main actors on the site were the Agency for the Assessment and Application of Technology or *Badan Pengkajian dan Penerapan Teknologi* (BPPT), the local government of Sumba Island and the electricity monopolist. The project took place in the southwest and west part of Sumba Island. The goal of the smart microgrid project was to test the functionality of the novel technology in order to increase the efficiency of the existing power plants. Specifically, the electricity infrastructure in west and southwest Sumba was mainly supported by three hydropower generations in Lokomboro district, a diesel generator in Waikabubak district as well as a diesel generator in Waitabula district. The total potential electricity production from those generations was around 1.8 MW (Prastawa et al. 2013). The daily baseload was between 1.2 MW to 1.5 MW (Djamin et al. 2012). During the project, a smart controller between on grid electricity generators was placed to optimize power production and power dispatch. The main location of the smart grid controller was in Bila Cenge Village, Kodi Utara district in Southwest Sumba. In addition, a PV subsystem with a total capacity of 500KWp and its storage subsystem were also installed to the project.

The specification of the Smart Microgrid in Sumba is as follows:

Table 5-1 Specification of smart microgrid in Sumba

Focal Entity	Ministry of Energy and Mineral Resources (MEMR)
Name of Niche Project	Sumba smart Microgrid
Location	Bila Cenge Village, Kodi Utara, Soutwest Sumba, Sumba Island, East Nusatenggara Province
Type of Smart grid Technology applied	Microgrid with smart controller on grid
Specification	• PV subsystembs (1 unit) with total capacity 500 kW p; • diesel generator in Waikabubak (9 unit) with total 2300 kW; • diesel generator in Waitabula (6 unit) with total capacity 2170 kW; • Hydro Power plant in Lokomboro (5 unit) with total capacity 1800 kW; • Battery with total capacity 2 p 240 kWh. • SCADA (Supervisory Control and Data Acquisition) System.

Source: (Prastawa et al. 2017; Badan Pengkajian dan Penerapan Teknologi (BPPT) 2018)



a) Map of location of Sumba smart microgrid project
Source: (Prastawa et al. 2013)

b) Examples of parts of installed power generation that belonged to Sumba smart microgrid project

Source: (Armansyah et al. 2012; Badan Pengkajian dan Penerapan Teknologi (BPPT) 2017, 2018; Djamin et al. 2012; Prastawa et al. 2013, 2017)

Figure 5-6 Map of location and parts of installations smart microgrid project in Sumba island

5.3.2.2 Characteristics of entrepreneurial activities related to Sumba Smart Microgrid project

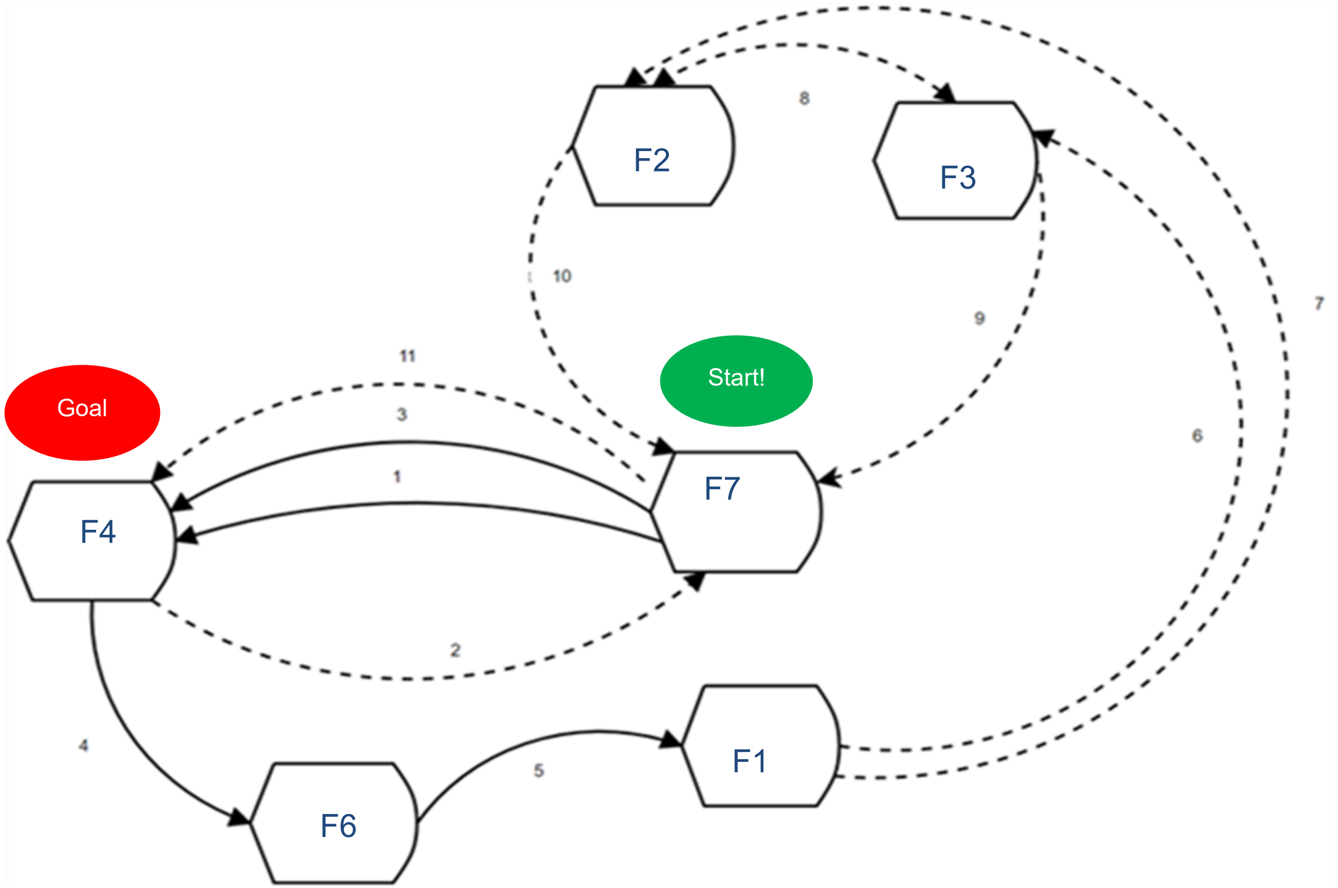
According to the theory, the project can be categorized into the first level of entrepreneurial activities or in a group of niche creation or technological niche. This is due to the goal of the project being to test the feasibility of the novel technology in a real situation and whether the innovation could provide either economic or technical benefit to the user so that it could be sounded to a national level about the impact of the innovation. In this context, the type of engine or motivation of the project can be categorized as the knowledge motor because it is mainly focused on conducting experiments or exploration related to the novel technology and sharing the knowledge about it .

Instead of starting with a top-down program from government, the project of a smart microgrid in Sumba showed that the project came from initiatives from communities that had the interest in microgrids, especially local research organizations. In this case, the government tended to adopt a bottom-up policy related to the novel technology, by accommodating, coordinating, giving recognition and providing resource access through a particular program for stakeholders that already had projects' plans or ongoing activities. The project also showed that support from the government was not automatically available. The collaborative movement in the case of Sumba was started through the capacity of stakeholders to create a room for negotiation or discussion with policy makers.

Furthermore, in the case of Sumba smart microgrid, the reason for stakeholders to engage in negotiation with the government, especially with the energy policy maker, was because the entity was seen to have the capacity in terms of social networking, political influence as well as financial resources in the region. In other words, those actors might gain more expertise, an increased number of potential project partners as well as more opportunity to reduce costs while utilizing the technology if they and the energy policy maker work together in one co-operation agreement. On the other hand, to come together in a collaboration project with those stakeholders was also positive from the perspective of the energy policy maker. It could give the body a positive image and a sense of urgency towards the importance of electrification process in poor regions using green technology.

Based on Figure 5-7, it can seen that in order to move the project, the main component of the engine of on-site experimentation was recognition from the government in the form of programs or visions which could facilitate project executors to access funding or licenses from the local society to deploy the project. At first, in order to have the available program from the government, the stakeholders should at first conduct negotiations or a series of lobbying activities with the energy policy maker. Other types of actions that were undertaken within the projects included funding, on-site pilot project, studies, and knowledge sharing. Figure 5-7 also describes the links between actions done by stakeholders in carrying out the smart microgrid pilot project in Sumba Island. The dotted line expresses a rather weak correlation between two actions, whereas a straight or unbroken line depicts a notable correlation between two actions.

After the negotiation was successfully responded to by the energy policy maker through the issuing of a program (the so-called Sumba Iconic Island), the BPPT (*Badan Pengkajian dan Penerapan Teknologi/ Agency for Assessment and Application of Technology (BPPT)* engaged its first around of lobbying with the energy policy maker in 2011 (Prastawa et al. 2017). It was aimed at seeking funding as well as technical support in order to establish a demonstration project of smart grids on Sumba Island under the umbrella of the Sumba Iconic Island. The research centre was then granted a funding scheme from the energy policy maker. After the funding was given, the pilot project was started officially in 2012 (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2018). The implementation of the project was under a partnership platform which consisted of local government, the electricity monopolist and the energy policy maker. The BPPT designed, installed and tested the functionality of the technology, whereas the utility offered its facility to be installed with the smart grid. The utility also deployed its local operators to complete maintenance work. The headquarters of the BPPT was in Jakarta and its researchers were not able to always be on site. Around two years after its initiation, the project successfully produced several results. This stimulated opportunities for stakeholders within Network 1, especially among academic entities, to conduct knowledge sharing or studies related to the project in order to sound the project. Because of this enthusiasm, the BPPT was encouraged to conduct the second round of lobbying in order to access further funding support to expand the project under the current program or to enable the energy policy maker to create a new program. This is the basic idea about how the project could be sustainable.



Note:

F7: Lobbying;
F4 : Program issued by policy maker;
F6:Funding/Grant facilitated by policy maker;
F1: Demonstration project to test novel technology;
F2: Studies;
F3: Knowledge Sharing;

Source: Own Depiction

Figure 5-7 Innovation motor applied for implementation of smart microgrid in Sumba island (2009-2019)

Furthermore, there were several factors that were likely to be correlated with the sustainability of Sumba smart microgrid project. Firstly, the capability of the BPPT to create and propose a new idea about plans to extend the project to its potential project partners was the most important. In addition, the availability of a particular program which could facilitate or supervise the extension of the initial projects issued by the energy policy maker or central government, just like the Sumba Iconic Island program, was extremely needed. Other factors included thegeneral interest of all stakeholders within Network 1 or at a national level in sounding the project through studies, publications and sharing information.

Based on Figure 5-7, it can be seen that after the initial project was completed, the new idea from the BPPT to extend the project was required by its potential project partners, especially the utility. Meanwhile, in order to agree to extend the project, they also presumably considered the feedback or opinion of stakeholders within Network 1 towards the project through a series of knowledge sharing activities so that they could help the BPPT to negotiate with the energy policy maker. As the BPPT succeeded in attracting its potential project partners to join, they ought to contact the energy regulator to give them supervision under the Sumba iconic island program or other related program. As the energy regulator agreed, then the energy regulator, which played as the leader of the program, might act to facilitate the BPPT and its partners to get financing from the third party, or the energy regulator might fund the extension of the project by itself.

Nevertheless, the possibility of the project as a pioneer to introduce a smart grid technology had the potential to be stopped. It was mainly due to two reasons: the political condition and unsuccessful initial demonstration project. The dynamics of political condition may also have impacted on the quality of the program that shielded the project. In other words, dynamic political situations led to changes in the characteristics of programs issued by the energy policy maker (Microgrid Investment Accelerator (MIA) 2017; Reber et al. 2016; Asia-Pacific Economic Cooperation (APEC) 2013). It was possible for the regime to cancel the program right away. Furthermore, if the initial demonstration project failed or did not satisfy the stakeholders, there would be less interest for society as a whole (Allotrope Indonesia 2017; Arifin 2021a). There would be less activity in undertaking further studies and discussions about the pilot project or plans to extend the project. In a worst case scenario, there would be less drive for society to embrace the technology. Subsequently, there would be no more lobbying and no more funding for the next pilot project or other related activities. In the end, the circle of the motor of the niche would be stopped.

5.3.2.3 Dynamic role of energy policy maker in intervening in the Sumba microgrid project

In general, between 2010 and 2019, the energy policy maker acted dynamically towards microgrid projects on Sumba Island. By announcing the Sumba Iconic Island program in 2010, the energy policy maker provided collaboration opportunities between the BPPT and the utility as well as funding opportunities. Besides acting as a patron of the Sumba smart microgrid project, the energy policy maker also observed the project as an opportunity to test the overall concept, technological materials, functionality and suitability of the technology in Indonesia, especially in Sumba. In doing so, it even issued the so-called regulation of MEMR No. 3051K/30/MEM/2015 in order to give a stronger political legitimation towards various projects under the umbrella of Sumba Iconic Island program. The policy notably gave smart grid collaborators in Sumba access to a funding opportunity from the Asian Development Bank, with the Indonesian Ministry of Finance as the guarantor (Asian Development Bank (ADB) 2016, 2018).

The attention of the energy policy maker increased as the project moved forward, but then the support slowed down. In 2018, the government decided to reduce its interventions by giving a mandate to the state-owned utility/monopolist, as the main owner of the smart grid facility in Sumba Island, to manage the program further. The energy policy maker argued that the goal of the Sumba Iconic Island was too unrealistic. At the end of 2019, the renewable energy penetration in the electricity sector in Sumba only accounted for around 20,4% which was still far away from the initial target, which aimed to reach 100% renewable energy penetration (Perusahaan Listrik Negara (PLN) 2022). Even though the electrification ratio in Sumba increased from 24,5% in 2010 to 74,83% in 2019, it was mainly due to the expansion of the electricity infrastructure based on fossil fuels (Arifin 2020b). The energy policy maker then removed the goal of the Sumba Iconic Island and followed the advice of the electricity monopolist to only target less than 30% of renewable energy penetration for the electricity system in Sumba until 2025 (International Renewable Energy Agency (IRENA) 2020; Sutisna et al. 2020).

5.3.2.4 Characteristics of learning undertaken by stakeholders through the Sumba smart microgrid project

The Sumba smart microgrid project gave various stakeholders opportunities to learn more about the feasibility and potential of the technology in Sumba. There were some characteristics of the learning process based on the project within the boundaries of innovation Network 1 that was facilitated by the energy policy maker. These were as follows:

- Actors from outside Sumba island, e.g., engineers from the BPPT and the utility, which had their headquarters in Jakarta, brought their initial knowledge and skills about smart grids to the project in Sumba. Therefore, local actors in Sumba, for example local technicians and government, would strongly rely on them to carry out the project in Sumba together. However, due to the novelty of the technology and the many limitations of the project, for example restricted time frame, funding, human resources, and infrastructure, most of the local operators had difficulties in carrying out the project as well as to correct their failures. As an example, they mentioned the gap in expertise between local technicians and technicians from the capital city (Microgrid Investment Accelerator (MIA) 2017; Putra 2015). There were also problems related to communication between actors in Sumba (as executors) and actors in Jakarta (the policy maker or tacticians) which were costly and ineffective (Armansyah et al. 2012). Problems concerning the high cost of maintenance of PV panels and storage due to rats and insects around the facilities also arose (Prastawa et al. 2017).
- Publications concerning the project were limited and did not cover a broader range of stakeholders in the innovation network due to a high cost of consolidation and communication (Castlerock Consulting 2014; Prastawa et al. 2013).
- In order to gather opinion from the broader community as well as to improve the project with new potential equipment or a new system, an individual actor, particularly the BPPT, actively approached other new potential partners to become involve in the project. The Japanese Government, through *Kyudenko Corporation,* later joined the project by contributing to the control system of the project in 2016 (Akhmad et al. 2017).

5.4 Discussions: Would the network go to the next level when both technology and market were not yet ready?

The findings exposed in the chapter demonstrate that smart grid collaborative movements within the network facilitated by the energy regulator (Network 1) in Indonesia can be identified and then further analysed as a cell of a technological system of innovation (TIS).

Findings indicate that most of the collaborative projects were created by a limited number of actors in order to handle specific tasks in a specific range of time. In addition, the utilized resources and generated outcomes within partnership arrangements were managed and mostly owned by the initiators. Each involved stakeholder within a collaborative project usually had its own expertise or speciality, thus the division of labor was clear before the project was executed. This depicted a situation where the network neither prioritized common resource accumulation nor provided a more flexible way for stakeholders to create and utilize assets and goals together to enhance the sustainability of the network in order to grow into a system of innovation. This is in line with studies undertaken by Hurmelinna-Laukkanen & Nätti (2012) and Dhanaraj & Parkhe (2006); which show that most networks working for the diffusion of novel innovations are still dominated by a few powerful actors.

In Network 1, the government evidenced its intervention by forming more than one third of total collaborative projects in the network. It also disclosed several visions and additional incentives for stakeholders. It illustrated its deliberate efforts due to its central position within the network and political status to intervene in the size and characteristics of its network. Meanwhile, the stakeholders also had a high dependency on the entity in terms of existing linkages & affiliations, knowledge, finances, experience and long-term visions. Nevertheless, the energy regulator showed its drawbacks in enhancing its network by being potentially protective in its relationship with the current technology regime, specifically the incumbent firm. In this stage, the energy regulator used its leadership to conceivably prioritize the needs of the incumbent firm through several contra-productive measures towards its network. Meanwhile, the incumbent firm also expressed its domination in Network 1 by being builder and direct controller of almost one fourth of the total collaborative projects.

Furthermore, at a national level, the smart grid initiatives from the energy regulator can be categorized as using a top-down approach. It was part of the national rural electrification program, especially in the east of Indonesia, that was arranged together with several government bodies, including the Indonesian ministry of national development planning, local government and the state-owned utility (Mandelli 2014). This is equivalent with the findings from (Davidson et al. 2016; Gallop et al. 2021; Isoaho et al. 2017), where innovation movements dedicated to renewable energy technologies in emerging countries were mostly through top-down initiatvies from policy makers.

Subsequently, it is found that the potential problem that existed within the network was related to the choice of the technology priority, the smart microgrid, that was aimed at enhancing the decentralization of power systems based on renewable energy. It was not due to the lack of potential solutions provided by the technology, but due to local conditions that seemed very difficult to adopt the technology. In poor rural and remote areas in most of the eastern regions in Indonesia, it was extremely difficult for the local community to have their own distributed power generation, even in a communal way. On the other hand, their priority was still to gain access to reliable and affordable electricity. In perspective of the local society, the novel techno logy was quite beyond them. In addition, the technology was not yet compatible with the local infrastructure, especially the availability of stable internet connection. The only way to explore and then adopt the technology was through using existing power plants owned by the incumbent firm in the local area.

Modification of the prototypes were also required to suit the local conditions. In order to do this, particular people were needed to be invited to redesign, install, test and operate them. Most of those people were from the capital city. At this level, there was an option: to open permanent jobs for experts in those regions or to train the local operators (Allotrope Indonesia 2017). This takes time and is costly, therefore, the government may also face challenges so that the installation of the novel technology could perform in a stable manner. In addition, the other issue was related to the dominance of local government and state-owned utility as the main instruments of government to implement rural electrification program. This left several problematical difficulties related to complexity of the bureaucracy that took place in most of the government offices and the utility, when individuals or NGOs planned to conduct investment in those regions (Arifin 2020c; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) 2013).

Nevertheless, the findings show that the bottom-up approach was also implemented by the energy regulator. Sumba Iconic Island program, announced in 2010 and formalized in 2015, was one of the bottom-up initiatives of the energy regulator. It was issued in order to provide legitimacy to existing decentralized on-site experimentation projects completed by non-governmental bodies. The program was released also after a series of negotiations or dialogues between government and independent smart grid project implementers, especially NGOs and universities. In the program, the energy regulator acted as enabler of communication between independent project implementers and important stakeholders, such as local government and utility. It also acted as a middle-man between project executors and financial institutions. The negative aspect was that there was a time when the government lost interest in continuing the program. This happened in 2018 when the energy regulator decided to step back from the program and leave the rest to the state-owned utility/incumbent firm.

In general scope, the results show that Network 1 was still in the early stages of development in implementing systemic functions because it still focused its role as a platform for getting to know the characteristics of the technology. In terms of activities, the network dedicated more than half of the total collaborative projects to knowledge sharing and exploration within academic domain. Most of the technologies that were undertaken in projects were in the form of prototypes with the potential to be tested in local situations. There were also a significant number of projects that were discussed at the level of ideas and concepts. In addition, the population of actors within Network 1 was dominated by experts from the incumbent firm and universities, especially the local and public research centres. Nevertheless, the engagement of stakeholders at regime level was also rather noticeable. They created almost one fourth of their total projects in providing policy recommendations as well as meetings and negotiations to prepare lobbying activities with politicians. Active movements at a grass-roots level also took place, including on-site demonstration projects and independent knowledge knowledge in communities.

Meanwhile, in a more specific scope, the study observed an on-site demonstration project of the smart microgrid in Sumba as a sub-case study of Network 1. The project was at the early phase of niche experimentations. It still focused on exploring the pre-mass-marketable product by testing its suitability and functionality in local conditions. According to the theory, it can be classified into niche creation or the early phase of entrepreneurial experimentation. In addition, the project was implemented due to a support program from the government and had the objective of maintaining the support program so that the project could last longer and deliver a more significant result. Most of the involved players were from public research centres and the incumbent firm belonged to government. The finding was in line with the theories, where the creator of the motor of innovation was the government through its capability in issuing program or funding opportunities. Nevertheless, the results show different conditions with the previous studies done by Gosens & Lu (2013) and Suurs (2009). Those studies refer to the program as a top-down program for enhancing knowledge exploration, however, the results in the chapter showed that the program that related to Sumba applied a bottom-up policy from the government. In other words, the program existed due to the results of a series of lobbying of project stakeholders with the government. At this level, the project executors saw the government as the prominent entity that could provide them legitimacy, prestige, support and networking due to its economic and political power. In addition, the results show that within the context of Indonesia, lobbying was a very basic function that was required to be conducted, even in the early phase of building a system of innovation. This is also in-line with studies done by Isoaho et al. (2017), Mainali (2014), and Bergek et al. (2008c). In this stage, the motor of innovation worked due to both the capacity of project implementers, specifically the public research centres or representatives of innovators, to deliver positive outcomes to expand or to continue their projects, and the willingness and capacity of government to provide program or funding opportunities related to novel technology.

5.5 Summary

The chapter shows that, in general, Network 1 was still in the very early stage of growth into an innovative ecosystem for smart grid technologies. It was based on the application of dominant network orchestration in forming and executing the majority of collaborative projects which conceivably led to an imbalance between a high dependency of stakeholders on leading actors, specifically the energy regulator and the incumbent firm, and actual positive intervention of leading actors towards their network. In addition, exploring and sharing knowledge about less sellable novel technology in local markets was still the activity that was predominantly undertaken in the network.

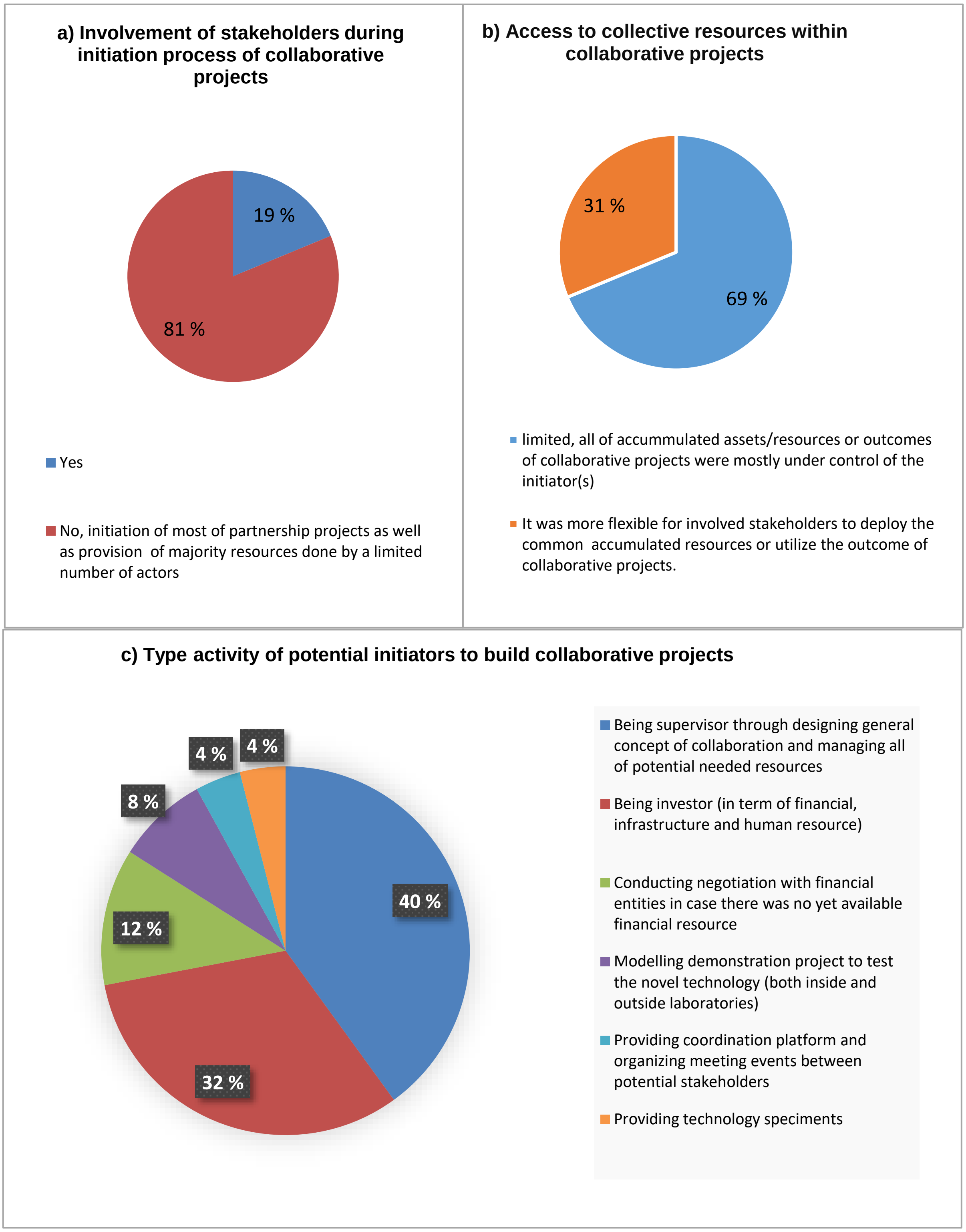
6 Case 2: The Innovation network for smart grid technologies in Indonesia led by the incumbent firm (The Network 2)

This chapter illustrates the dynamics of an informal innovation network for smart grid activities in Indonesia that was mainly led by the incumbent firm, specifically the Indonesian state-owned utility, from 2009 to 2019. In this chapter, the development of the network as an embryo of a system of innovation is described through its characteristic in managing collective resources, the existence of intervention of leading actors in influencing stakeholders and performance in implementing the functions of system of innovation.

6.1 Few elite stakeholders dominated the network resource orchestration

Based on the results of the on-line survey provided in Figure 6-1, more than 80% of total collaboration platforms within Network 2 between 2009 and 2019 were created by a limited number of actors. It is also shown that those initiators also provided the majority of resources needed for those projects. Subsequently, almost 70% of on-line survey participants claimed that there was no flexibility for them to deploy assets belonging to their projects or be freely utilizing the outcomes generated from those projects because those were not theirs from the beginning but belonged to initiators.

Meanwhile, only 19% of on-line participants reported being involved in the formation process of collaboration projects in their network or implicitly named themselves as potential initiators (See Figure 6-1). According to them, the resources required during the formation process of collaborative projects was prepared by at least two initiators, for example the conceptualist and the investor. Furthermore, there were several ways for initiators to introduce their projects. In Network 2, most of the project creators started their activities through several activities, including from designing the grand concept of projects (40%), being resource provider in terms of finances, infrastructure and human resources (28%), or conducting negotiations with financial entities in case there was not yet budget availability for those projects (12%). In addition, a small portion of potential collaborative project initiators also showed their activities through proposing a particular demonstration project of the novel technology (8%), providing coordination platforms/organizing meeting events (4%), and providing technology specimens (4%).



Source: Own depiction

Figure 6-1 Characteristics of resource orchestration applied in collaboration projects within network 2 (2009-2019)

In addition, expert-informants argued that, in general, they joined in collaborative projects after those projects were established or ready to be carried out. Usually, they were asked to accomplish a certain task on projects where the copyrights of the outcomes belonged to the initiators.

''We joined in a partnership project normally after the project was already set. We did a rather a specific task. It was not easy to arrange or to create a cooperation project. It was conducted usually by either the authorized government agency, the utility, smart grid firms or organizations which had already financial access.'' (Interviewee Nr. 5).

''We are scholars. We were normally invited to join in a specific project related to smart grid within circle of the utility as professionals. We were working under management or supervision of the initiator of those projects and the results were owned by the initiators under a particular agreement with us.'' (Interviewee Nr. 7).

Regarding the utilization of assets belonging to collaborative projects, stakeholders argued that the project initiators, especially for on-site projects, would likely dominate the administration as well as the implementation of the projects. Those initiators usually had the authority to manage the assets as well as the relationship among stakeholders within a project. Nevertheless, for projects which were aimed at desktop studies or sharing information, the resources in the projects were claimed as common goods.

''Of course, the initiator(s) would likely have control of the assets or resources of their projects because they had the idea, money, or technology specimen from the beginning. For example, smart grid companies which introduced some pilot projects in Indonesia.'' (Interviewee Nr. 7).

''In perspective of smart grid innovators, I think they were active during a creation and dominated the implementation of a collaboration project because they had the technology specimen and they wanted to make sure that the project would be ready and successfully carried out.'' (Interviewee Nr. 8).

'' Some projects that offered a flexible use of resources, e.g., communication platforms and contacts, to their stakeholders were projects that mostly handled scientific events, for example seminars or webinar.'' (Interviewee Nr. 6).

6.2 Intervention of the incumbent firm as a focal actor in its innovation network

6.2.1 The incumbent firm had less potential than the energy policy maker in controlling its own network

Based on an analysis of using a social network approach, Figure 6-2 describes the value of social network indices, including the degree of centrality, closeness centrality and betweenness centrality of each category of stakeholder in Network 2 on average. At first, the results show that the network had an average score of degree centrality of 0.258. This depicted a situation where the network was extremely decentralized or almost all activities were undertaken by stakeholders autonomously or in a generally uncoordinated fashion. In addition, the network experienced a very low score of closeness centrality (0.324) as well as a low score of betweenness centrality (0.184). This shows the average capability of stakeholders in conducting information sharing as well as building co-operation projects was potentially low.

Theoretically, a decentralized network with a weak connection among its members would likely provide more benefit to a stakeholder which occupies greater centrality due to its high recognition because of either a political position or economic and social status.Thus, due to its prominent position, it conceivably influences the network. At the same time, the result provided in Figure 6-2 shows that the energy regulator had the greatest potential capacity to govern Network 2. It had an average social network index of 0.89, together with an average value of degree centrality of 0.95, an average value of closeness centrality of 0.95 and an average value of betweenness centrality of 0.76. Those numbers described the high capacity of the national energy policy maker to control information as well as to coordinate most of the stakeholders within Network 2. Meanwhile, the state-owned utility had the potential to be the second controller of Network 2. It had an average value of social network index 0.69. In addition, it had the capacity to disseminate information (closeness centrality index =0.78) and a significant power to consolidate other stakeholders (degree of centrality =0.72). However, it did not have a very strong capacity to enhance partnerships among stakeholders within Network 2 (betweenness centrality =0.57).

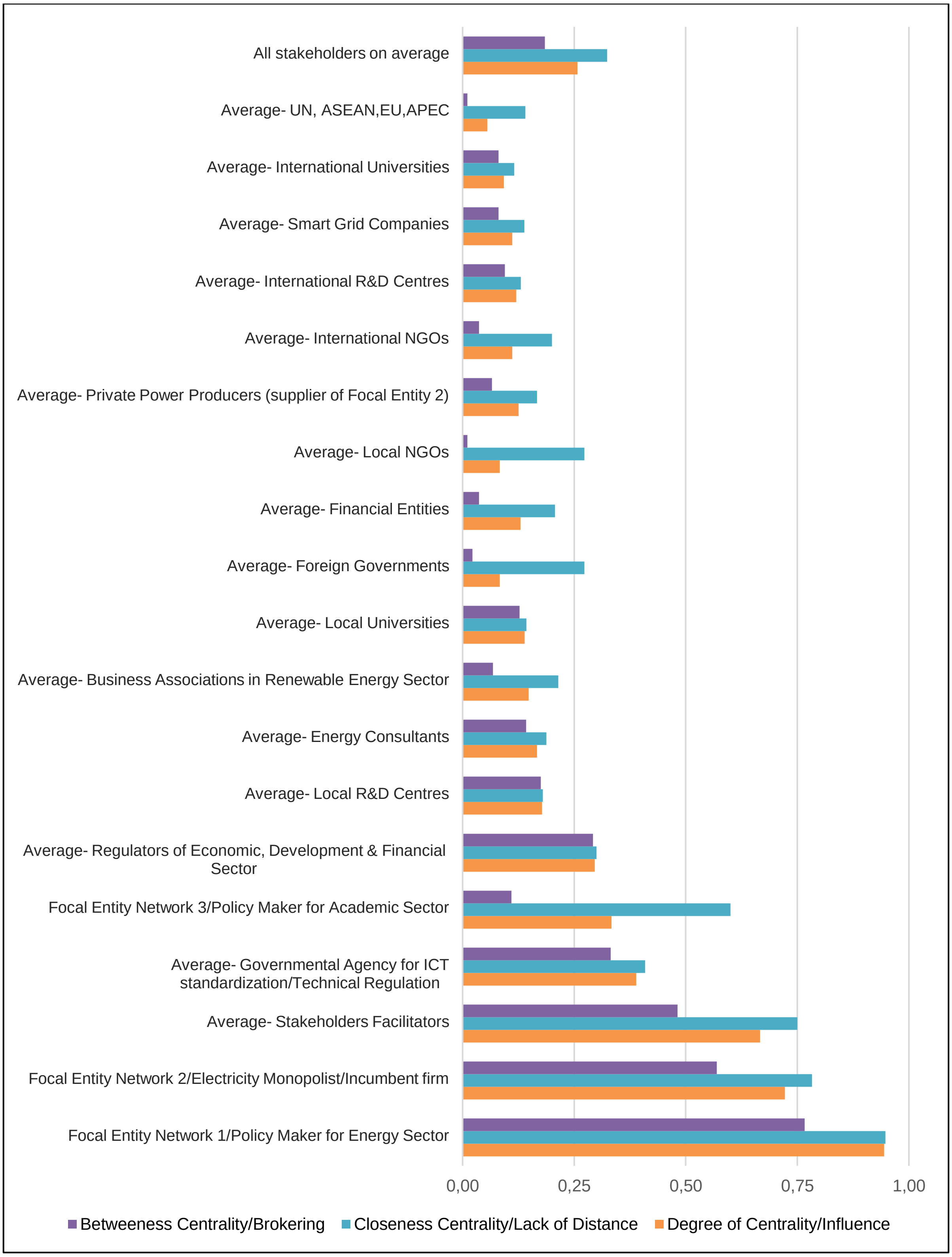
In addition, Network 2 was described by the expert informants as the business network owned by the electricity monopolist. However, because the company belonged to the government, the management or capacity of the corporation was highly influenced by the political regime or policy maker.

''Even though the incumbent firm was the monopolist, all the financial policy related to the company was totally influenced by the policy maker of energy and the policy maker for economic & financial planning, since the company was belonged to the state.'' (Interviewee Nr. 5).

''In every way, the business done by the utility was heavily influenced by the central government. But the company itself needed the government in order to survive as monopolist, especially in a situation where many kinds of innovations in energy systems came up and possibly could enhance such as a market reformation, therefore it was possible that its network was mainly managed by the central government.'' (Interviewee Nr. 6).

Meanwhile, the stakeholder facilitators that included the Indonesian Smart Grid Initiative, were in third position to influence Network 2 (See Figure 6-2). It had a significant potential role to provide a communication platform for stakeholders (closeness centrality index = 0.75) and to bring together most of the stakeholders (degree of centrality=0.67). The policy maker of research and higher education also had a unique position in Network 2. It neither integrated nor initiated cooperation among stakeholders within the network. However, it had a significant value of closeness centrality index (0.60) that made it effective in circulating information among the majority of stakeholders in Network 2.

The result also shows the average capacity of each academic entity to influence the network was very low (See Figure 6-2). For example, a single local research centre had an average social network index of 0.18, a single local university/school had an average social index of 0.137, and a single international research centre had an average social network of 0.12.



Source: Own depiction

Figure 6-2 Different value of social network indices between different groups of stakeholders of Network 2 (2009-2019)

6.2.2 Actual Intervention of the incumbent firm in its innovation network: Between nurturing and controlling

6.2.2.1 The incumbent firm together with the energy policy maker: Acting better in controlling than initiating collaborative platforms

According to the results of the on-line survey, the incumbent firm (monopolist) successfully created around 19% of the total collaboration arrangements within Network 2 between 2009 and 2019. Meanwhile, in that period, smart grid companies initiated around 33% of total partnership projects within the network, followed by the energy regulator which initiated 24% of total collaborations. NGOs played an important role in Network 2 as well. It generated 10% of total cooperation platforms. Additionally, other types of organization that contributed to the formation of collaboration projects within Network 2 were intermediaries/stakeholder facilitators (5%), ASEAN (5%) and universities (5%). It depicted a reality where the introduction of new technology within the network was initiated neither by those powerful government related organizations nor by the utility, but by the technology creator or industry. Other than that, the result also shows the similarity from the social network analysis, where the policy maker was indeed more powerful than the utility in building cooperation among stakeholders within the network.

The cooperation projects that were Initiated by the smart grid firms were basically aimed at testing certain types of smart grid technology in a specific location or building a network to market their product. On the other hand, the collaborations that were formed by the utility and the energy policy maker were about policy making to regulate the activities of stakeholders, including projects about standardization related to smart grid technologies and setting the goal and priorities of the stakeholders. Collaboration platforms enhanced by other stakeholders, for example NGOs and academics, mostly focused on desktop studies and knowledge sharing activities regarding the most up-to-date smart grid innovation or evaluation of ongoing smart grid projects in Indonesia.

Nevertheless, according to the expert-informants, the limited contribution of the utility in creating collaborations within the network did not refer to the absence of the company in intervening in the sustainability or the development of almost of all planned and ongoing collaborations within the network. With agreement from the central government via the energy policy maker, the utility, through its authority in controlling national grids and its electricity consumers, was able to decide whether a certain cooperation project should proceed, be delayed or cancelled. For more details, a project proposal which consisted of on-site demonstration projects or the installation of a specific smart grid technology in houses of the utility's consumers required a significant amount of time to gather approval from the utility as well as from the energy regulator. Meanwhile, 50% of on-line survey participants claimed that the process of creating a partnership platform in the network was slow. 13% of on-line survey participants reported that the process was very slow.

‘’For us, there were more projects for installing a very new technology, for example a PV smart metering, in households. (But) it took more than half a year to get the license from the government to apply the technology.” (Interviewee Nr. 8).

‘’An on-site pilot project needed a permit from as well as cooperation withm both the utility and the energy policy maker to be able to be carried out. In addition, it usually needed coordination with local stakeholders, for example local government. Those required big efforts. Nevertheless, seminars or conferences were rather easier to be organized than a pilot project in a specific location.” (Interviewee Nr. 7).

6.2.2.2 The incumbent firm approved of the energy policy maker to control the network

From 2011, the utility showed its interest in smart grids by opening up the possibility for its consumers to have a more transparent service, smart pre-paid electricity and to be able to conduct the export-import of electricity to the grid by using prosumer smart meters. However, as the population of prosumers increased dramatically as well as the demand for more sustainable, efficient and transparent electricity systems from those prosumers becoming inevitable in the following years, the incumbent firm turned to the central government to solve the issue (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2013). From 2014 onwards, the government decided to take control of business activities of the utility, which included its activities related to smart grids by regularly enforcing the annual operational plan of the utility, the so called The Electricity Business Plan or *Rencana Usaha Penyediaan Tenaga Listrik* (RUPTL).

- The RUPTL 2015-2024, RUPTL 2016-2025, and the RUPTL 2017-2026 mentioned the importance of developing a two-way communication system between electricity producers and consumers as well as smart decentralized power systems based on renewable energy in small and remote islands in Indonesia (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2015a, 2016a, 2017a).
- The RUPTL 2018-2027 described the smart grid pilot projects in Indonesia (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2018a). Those included the negotiation of smart city projects in industrial regions of Surya Cipta Sarana, Karawang , West Java Province that were initiated by the NEDO (The New Energy and Industrial Technology Development Organization- Japan), smart meter pilot projects in Batam and Bali Island, PV Prosumers- Smart Metering in Jakarta City , and a Microgrid Project on Selayar Island.
- The RUPTL 2019-2028 mentioned the plan to initiate negotiations for electric vehicle projects, regulations for PV Prosumers and microgrid-on grid projects in rural areas in Indonesia (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2019b).

The annual business plans that were guided by the energy regulator were then initiated by the utility. At first, the utility followed the RUPTL by issuing its own smart grid activity plans which consisted of a declaration of the utility as a pioneer of smart grid technologies in Indonesia and its main activities to be followed by the stakeholders. In 2014, the company disclosed a smart grid roadmap (Perusahaan Listrik Negara (PLN) 2016). It was basically a strategic plan from the company on how to adopt smart grid technologies in order to enhance productivity and efficiency of performance of the company itself. The document stated that the utility, as the electricity monopolist, took the initiative in developing smart grids in Indonesia through the application of smart metering systems for PV prosumers, pre-paid electricity systems and distributed generation control for microgrids. Subsequently, in 2015, it issued its company smart grid road map for 2016-2021 (Perusahaan Listrik Negara (PLN) 2017b). The plan mentioned that productivity solutions based on smart grids were very important to prevent or to reduce black outs as well as to minimize feeder outage. In addition, two-way metering infrastructure and decentralized smart power systems in smaller or isolated islands should also be introduced as an important priority for Indonesia.

Furthermore, to lead the implementation of the RUPTL as well as to assist the utility, the energy regulator issued technical and financial policies in order to influence the stakeholders. For example, the technical and financial measures for the PV prosumers through the Decree of Ministry of Energy and Mineral Resurces (IMEMR) No. 49/2018, No. 12/2019 and No. 13/2019 (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2018c, 2019c). Through these measures they strongly regulated and monitored the application of PV prosumers, from providing a rather perplexing licensing application process to imposing a controversial offer of import / export price agreement to the grid (comparison 1:65 for import / export energy).

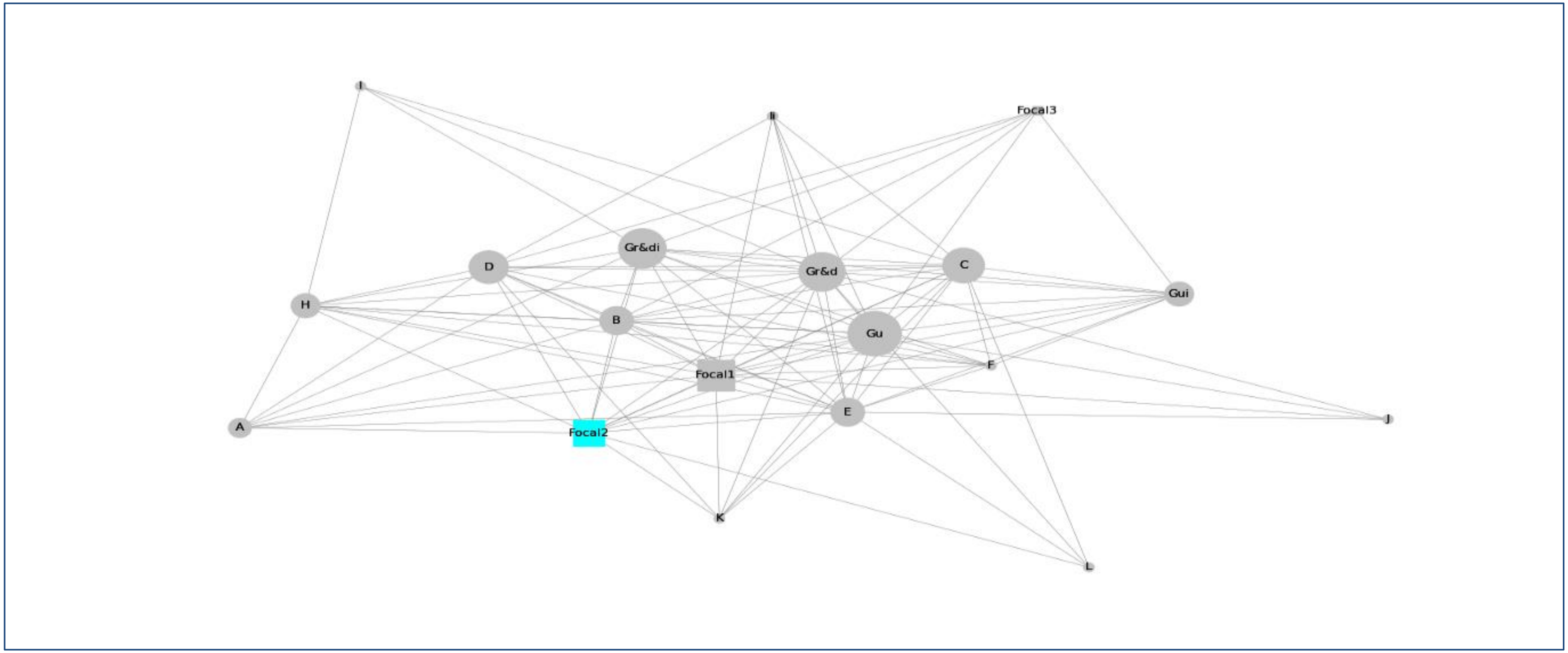
6.3 Performance of the network in implementing the functions of a technological innovation system (TIS) of smart grid technologies: Existence of further various players attempting to fulfill different functions

6.3.1 Performance at a macro level through collective - collaborative actions

6.3.1.1 Diversified Players

Network 2 consisted of various types of organizations. According to the number of links that the stakeholders had (based on the on-line survey), there were five organizations that acted as main players in the innovation Network 2 (case 2) from 2009 until the end of 2019 (See Figure 6-3). Those organizations included the utility itself, the policy maker for the energy sector, local research centres, the policy maker for the development and financial sector, and the governmental agencies for ICT and technical standardization. All organizations within the network had a direct connection with all those main players, except for local NGOs, supra national organizations, e.g., UN and ASEAN, and foreign governments.

In addition, in Network 2, the size of each organization within the network was diverse. The research calculated the size based on the distribution of organizational backgrounds of experts of on-line survey participants. Figure 6-3 depicts that the size of local universities, local research centres and international research centres were bigger than other organizations. It shows that smart grid activities within Network 2 strongly involved various academic entities. Nevertheless, other types of organizations were also illustrated to have a noticeable size in the network. Those included the energy regulator, the incumbent firm, the government official for ICT/technical regulation, and meeting platform providers. In addition, the size of actors that had a direct connection with end-users, such as smart grid companies and private energy consultants were also visible in the network.



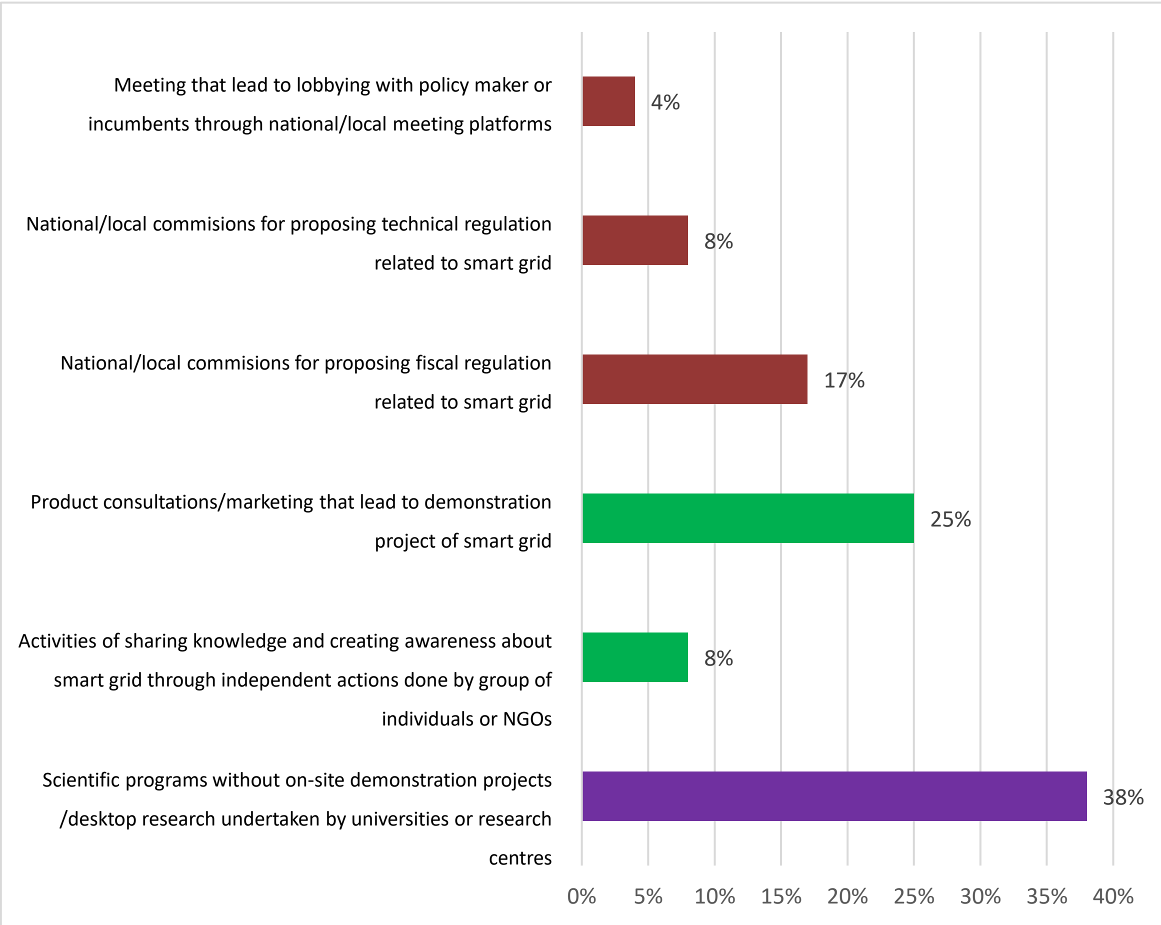
Code	Description		Code	Description		Code	Description		Code	Description
A	Business Association in Renewable Energy Sector		**F**	Private Power Producers (supplier of Focal Entity Network 2/Monopolist)		**H**	Smart Grid Companies		**K**	Financial Entities
B	Energy Consultants		**Gu**	Local Universities		**I**	Local NGOs		**L**	Foreign Governments
C	Governmental Agencies for ICT standardization/Technical Regulation		**Gr&d**	Local R&D Centres		**Ii**	Int' NGOs		**Focal 1**	Focal Entity Network 1/Policy Maker for Energy Sector
D	Stakeholders Facilitators		**Gui**	Int' Universities		**J**	UN, ASEAN,EU,APEC		**Focal 2**	Focal Entity Network 2/Utility-Monopolist
E	Regulators of Economic, Development & Financial Sector		**Gr&di**	Int' R&D Centres					**Focal 3**	Focal Entity Network 3/Policy Maker for Education/R&D

Source: Own depiction

Figure 6-3 Feature of connectedness among different groups of stakeholders within Network 2 (2009-2019)

6.3.1.2 Collective activities that reflected a desire for innovation in academic, niche and regime domains

According to the on-line survey, Network 2 was quite successful in implementing diversified collective activities in order to create a more innovative ecosystem for smart grid technologies in Indonesia (See Figure 6-4). Different types of functions of technological innovation system through collaborative projects were implemented by the network. Scientific activities such as R&D and knowledge sharing activities were mainly carried out on campuses with rather limited contact, either with end-users or with smart grid companies, contributed to around 38% of total collaborative projects within Network 2. In addition, collaborative actions at regime level included national/regional committees to propose fiscal regulation (17%), national/regional committees to propose technical regulation (8%), and meetings led for lobbying through national/regional particular meeting plarforms (4%). Meanwhile, activities at a grass-roots level consisted of product consultations led to demonstrate projects and involved a high possibility of direct contact between smart grid companies and end-users (25%) and actions of group of individuals in introducing smart grid technologies within the network were also considerable (8%).



Source: Own depiction

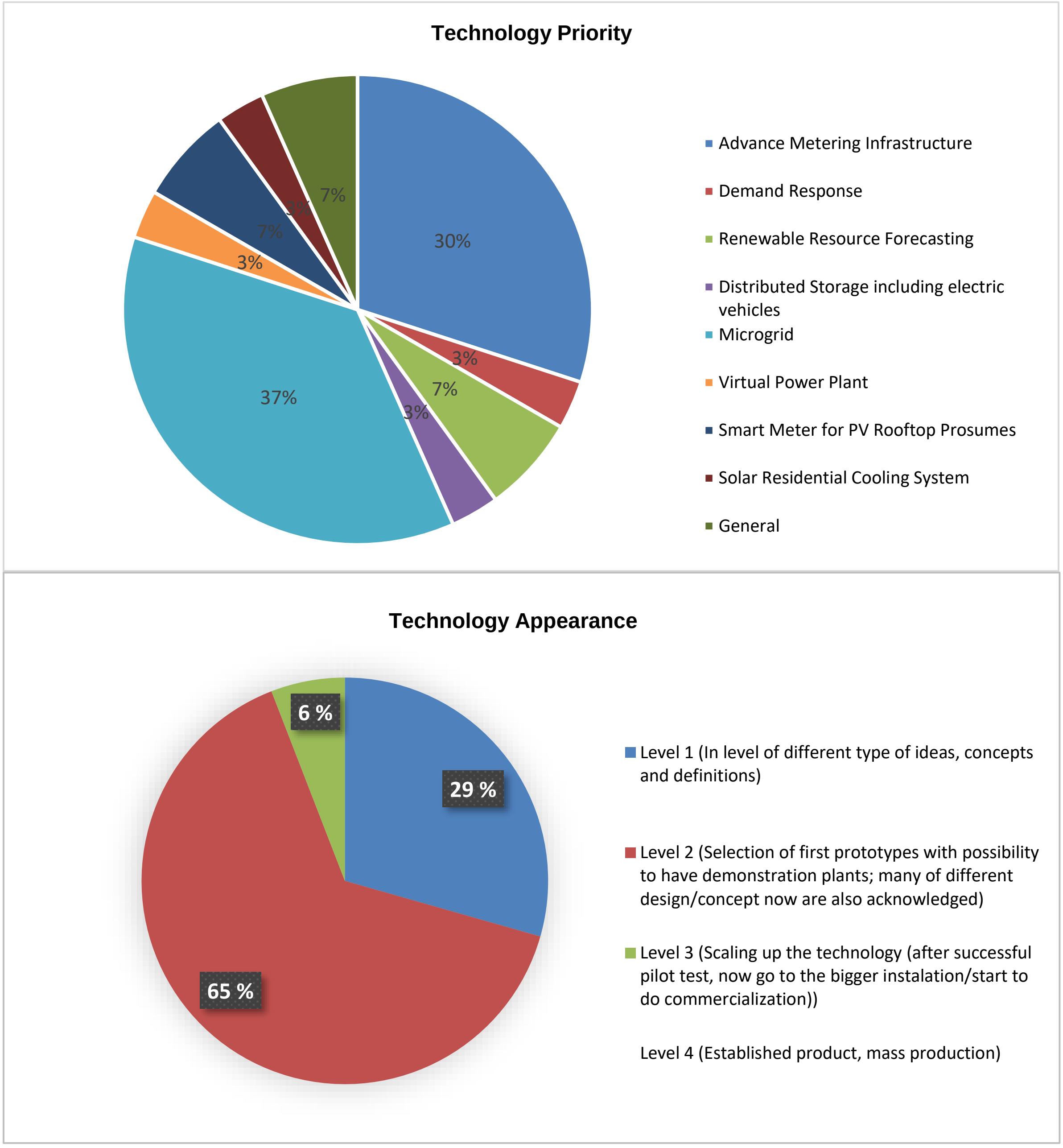
Figure 6-4 Collective activities to implement functions of a TIS within network 2 (2009-2019)

6.3.1.3 Appearance of technology in the form of prototypes with potential execution of on-site experimentations in more than half of projects

Figure 6-5 shows the priorities and features of technology among collaboration projects within Network 2. Smart applications for residential users were among the priorities within the network, including Smart Metering Infrastructure (SMI) (37%), smart meters for PV prosumers (7%), distributed storage that included electric vehicles (3%), solar residential cooling system (3%), and demand response (3%). Meanwhile, there were also projects that handled smart grid technologies related to power generation, for example microgrids (30%), virtual power plants (3%), and renewable energy forecasting (7%). These were in parallel with the roadmap based on the monopolist which encouraged smart meter strategy, e.g., pre-paid systems and real-time information of energy consumption, and testing of microgrid applications in rural areas.

Other interesting results from Network 2 were that there were also 6% of total projects that handled the technology at the level of scaling-up. It describes that there were a number of projects in Network 2 that reached a certain level where smart grid companies, end-users and third parties, especially government and utility were able to be involved simultaneously. This also encouraged end-users to contact the smart grid companies directly and opened up opportunities for energy consultants, e.g., local resellers or installers to be in the business. Because of this, the government had the opportunity to directly influence those projects through either fiscal or technical measures that may either enhance or hinder the projects.

In addition to that, the majority of the collaborative projects within Network 2 focused on the first selection of prototypes that already had a testing- site or demonstration plants (69%). This indicated that majority of smart grid technology that was handled in Network 2 was ready to be tested in a live situation in Indonesia. Furthermore, Network 2 also shows that 31% of collaboration arrangements were in the form of ideas, concepts and definitions. Those were potentially projects that were aimed at introducing and analyzing the potential of the smart grid technology in society. The role of the government at this level could be as a network provider in terms of financial resources as well as research guidance for the stakeholders.



Source: Own Depiction

Figure 6-5 Technology priority and technology appearance in collaboration platforms within network 2 (2009-2019)

6.3.2 Performance at a micro level through entrepreneurial experimentations: The case of smart meters for Rooftop PV prosumers in Jakarta, Tangerang, and Bekasi city

6.3.2.1 Background and specification of smart meters for Rooftop PV prosumers in Jakarta, Tangerang and Bekasi city

The dramatic decrease of up-front costs for PV systems around the world between 2010 and 2019 provided opportunities for Indonesia to adopt the technology (International Energy Agency (IEA) 2019). At first, several big scale projects were undertaken in rural areas in Indonesia at the beginning of 2010 (Kan et al. 2018). However, various problems arose during the process. For example, it took more than one year to finish the administration and licensing process for installation (The United States Agency for International Development (USAID) 2016; Rosyad et al. 2020; Dijakovic 2018). In addition, complications in land acquisition, a high dependency on government and the utility to supervise and control the project, a lack of capable local stakeholders as well as high costs of maintenance due to the specific local climate acted as barriers to the sustainability of the projects (Hamdi 2019; Outhred and Retnanestri 2015; Lontoh et al. 2016; Blum 2013).

Meanwhile, at the beginning of 2011, several high-income households within the capital city of Jakarta began to install PV solar rooftop on their properties (Bellini 2018). Many eminent government buildings also started to install the technology in that year. Two years later, the number of households which had rooftop solar PV increased significantly. Those households and government buildings were already consumers of electricity of the national grid; therefore, they sent a petition to the utility to give them access to sell their excess electricity production from their solar Rooftop PV system to the grid. The enthusiasm was greatly welcomed by the utility in 2014 by issuing the regulation that allowed export and import of electricity between private consumers and the utility without a gap between the basic level price for importing and exporting electricity to the grid (Perusahaan Listrik Indonesia (PLN) 2014). Since then, the number of prosumers in Indonesia increased dramatically. From less than 100 prosumers in 2011 to more than 2,500 prosumers at the end of 2019 (Tarigan 2020). The total capacity increased sharply from less than 1 MWp in 2011 to 11 MWp at the end of 2019 (Arifin 2021d; Perusahaan Listrik Negara (PLN) 2018). According to Perusahaan Listrik Negara (PLN) (2022), most of the prosumers were private residential users. It reached 87.06%. Meanwhile, commercial buildings had a share of around 8.2%; buildings belonging to government institutions had a contribution of around 2.7%; and public infrastructures, mainly public hospitals, provided 1.61% of the share of contribution (Arinalso et al. 2018; Benarto 2019). In addition, industrial buildings supplied only 0.3% of the total number of prosumers (Liebman et al. 2019).

Jakarta, Bekasi and Tangerang were three of main big cities in Indonesia as well as the residential area accounted for around 70% of private household- Rooftop PV prosumers in Indonesia. In 2019, there were 1,657 families that acted as prosumers with a total of installed capacity of Rooftop PV reaching 5,828 kWp (Haryadi et al. 2021; Citraningrum 2019). In those cities, household-prosumers tended to live closely to each other geographically. The data regarding the situation of prosumers in those three cities in 2018 was based on (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2018d, 2016c) the following:

- In Jakarta, it was in Pondok Indah Residence and its surroundings where many Rooftop PVs were installed. The total number of prosumers in Jakarta reached 612 households with a total installed capacity of 2,500 kWp. The range of the amount of daily load of each prosumer were on average between 20.00 kWh and 61.00 kWh.
- Bekasi City, on the other hand, had 571 household-prosumers with a total installed capacity of 2,135 kWp. These were mainly located in Kemang Pratama Residence and its surrounding area. The range of the amount of daily load of each prosumer was on average between 20.00 kWh and 55.00 kWh.
- In addition, Serpong and its surroundings were the hotspot of Rooftop PV household-prosumers in Tangerang City. The total number of household-prosumers in Tangerang city was 474 families with a total installed capacity of 1,093 kWp. The range of the amount of daily load of each prosumer was on average between 18.00 kWh and 50.00 kWh.

a). Map showing location of Jakarta, Tangerang and Bekasi (Left); Example of installation of Rooftop PV in buildings and private residential buildings in Jakarta (Right above and Right below)

Sources: (Googlemap 2022; Indonesian Ministry of Energy and Mineral Resources and Balai Pengkajian dan Penerapan Teknologi (BPPT) 2016; Perusahaan Listrik Negara (PLN) 2017; Tataruang 2022)

b). Example of a smart meter for Rooftop PV prosumers that was utilized in Jakarta

Sources: (Perusahaan Listrik Negara (PLN) 2016)

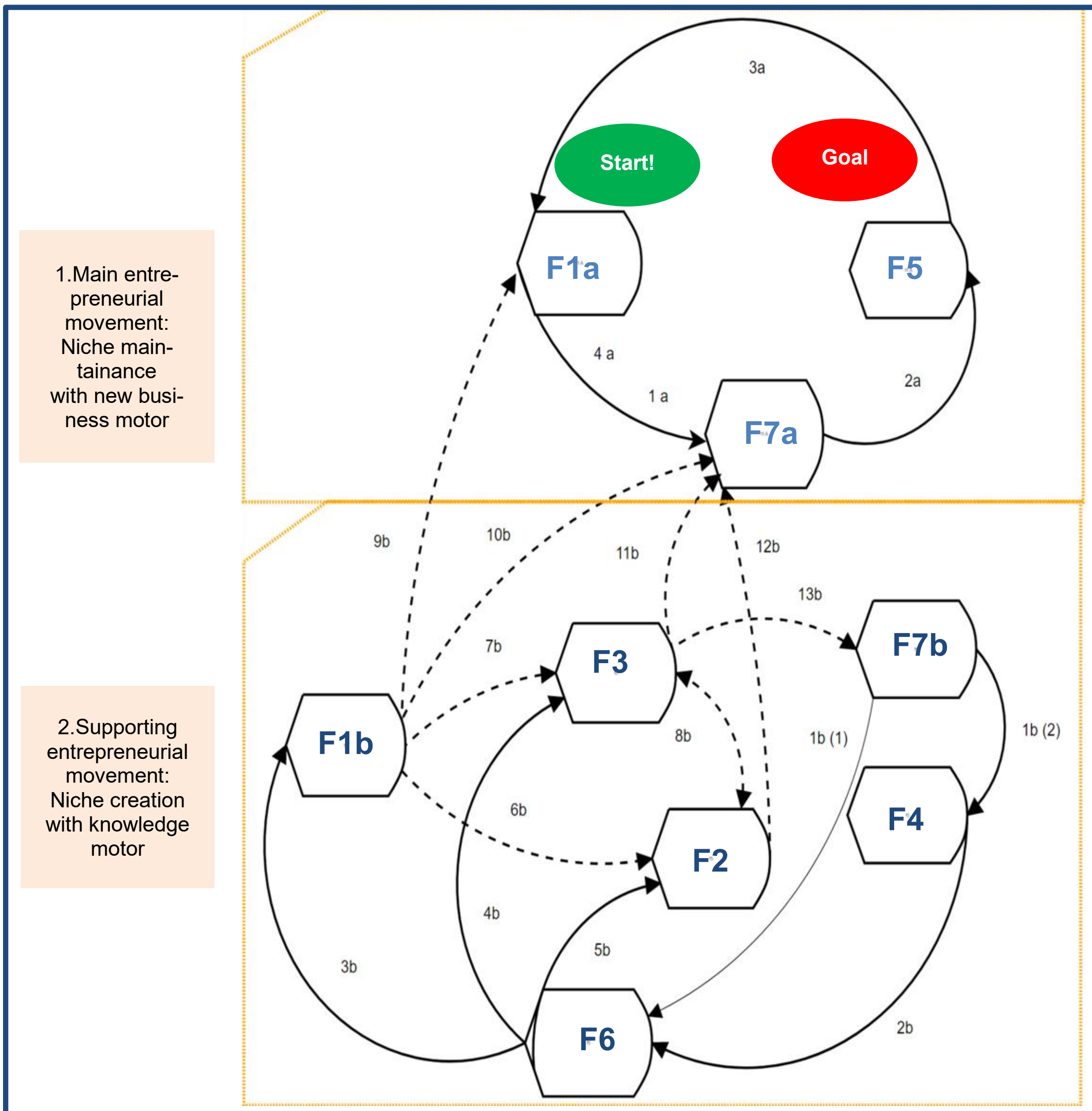
Figure 6-6 Map of location, example of rooftop PV installation, and a smart meter of rooftop PV prosumers within Jakarta

6.3.2.2 Characteristisc of entrepreneurial activities related to smart meter for Rooftop PV prosumers in Jakarta, Tangerang & Bekasi city

Figure 6-7 illustrates the early adoption of smart meters for Rooftop PV prosumers in Jakarta, Tangerang and Bekasi City. Related to this, the continuity of an entrepreneurial activity or on-site demonstration project can be seen from either the presence or the absence of links or cycles between functions done by each stakeholder. Furthermore, the cycle can be vicious or virtuous. In addition, the functions of system of innovation processes appeared in the case of PV solar rooftop prosumers in Jakarta, Tangerang and Bekasi City were undertaken through two groups that included the main entrepreneurial movement and supporting entrepreneurial movement.

The main entrepreneurial movement in this context was potentially classified to the second level of entrepreneurial activity or the so-called market niche or niche development. In this case, the activity aimed at increa-sing the size of the actual market or early adoption and to create possibility of having a protective space for the novel technology. On the other hand, the supporting entrepreneurial movement consisted of various projects that most of them were implemented to share knowledge and sounding out the potential of the techno-logy. Thus, in general, it can be categorized as the first level of entrepreneurial activity or niche creation.

Dotted lines connected the main movement to the supporting movement. It indicated an indirect or a rather delicate and unsustainable relationship between those two movements. The main movement consisted of actions that created an unbroken cycle. It shows a direct and strong correlation between various actions, e.g. pilot projects done by end-users, lobbying activities and fiscal policy deployment. The supporting movement, on the other hand, comprised of six functions, including lobbying, providing guidance / programs, funding, R&D activities, knowledge/information sharing, and undertaking demonstration projects. Activities in the supporting movement did not create an explicit unbroken cycle. It was therefore, it a sign that the sustainability of the movement might not as strong as the main one. In addition, actions within the supporting movement, such as demonstration projects, knowledge sharing, and R&D activities may only indirectly influence the lobbying actions conducted within the main movement.



Note:

F1a	: Early technology adoption in Bekasi, Tangerang, and Jakarta;
F5	: Fiscal incentive;
F7a	: Lobbying directly with policy makers dedicated to early technology adoption
F7b	: Lobbying with potential sponsors or project partners to create projects related to the novel technology (indirectly correlated to early adoption happened in Bekasi, Tangerang, and Jakarta)
F4	: Projects or programs related to the novel technology in Indonesia
F6	: Funding or investment dedicated to the novel technology in Indonesia
F2	: Research projects dedicated to the novel technology in Indonesia
F3	: Knowledge sharing dedicated to the novel technology in Indonesia
F1b	: Early adoption of the novel technology happened outside Bekasi, Tangerang and Jakarta

Source: Own Depiction

Figure 6-7 Innovation motors applied for the implementation of smart meters for rooftop pv prosumers in Jakarta, Bekasi, and Tangerang city

The business motor that enabled the main entrepreneurial movement:

According to the theory, an entrepreneurial movement which is already at the level of market niche may have either a new business motor or systemic business motor in order to move the movement. The new business motor focused more on early adoptions, whereas a systemic business motor is aimed at creating a mass-market for the novel innovation. Based on Figure 6-7, the main entrepreneurial movement is seen to have a new business motor. It comprised the adoption of technology by end-users at quite a limited scale, the pre-sence of a lobbying activity, and the appearance of fiscal policy. The main component or function of the motor was lobbying done by early adopters together with the novel technology suppliers. The action could either succeed or fail. If it was successful, then the fiscal policy came up to support the technology, so that the adoption would continue to evolve. Larger amounts of investment, for example in terms of technology acquisition as well as in investment in infrastructure, would also potentially take place due to the availability of the fiscal incentive. The improvement in technological utilization within the entrepreneurial movement enhanced the stakeholders to conduct a second round of lobbying. This was aimed at encouraging the government to update the existing fiscal policy. The better the fiscal policy, the better adoption of the technology. However, if the policy failed to accommodate or worsened the users, then the level of adoption would decrease. If this happened, at first, the stakeholders would conduct lobbying again so that governments could revise the actual fiscal policy. However, if the go-vernment was not able to respond or even tried hinder the lobbying, then the adoption of technology would be far more worsened.

In the case of PV Prosumers in Jakarta, Tangerang and Bekasi City, the new business motor was started through technology acquisition by households in Jakarta, Bekasi and Tangerang City. It was then followed by lobbying undertaken between stakeholders, specifically prosumers and smart meter suppliers, and government related bodies, specifically the incumbent firm which was also the state-owned company and the energy policy maker. The goal of the lobbying was to create a conducive financial environment for technology users. Subsequently, fiscal policy was issued by the energy policy maker. In 2013, the government was able to issue a regulation so that households had a right to buy and sell the electricity to the grid with export import price ratio of 1:1. This led the technology utilization in the main niche to grow exponentially. However, in 2018, the government decided to change the actual price ratio to 0.65 :1. It made households lose potential revenue of about 35%. In 2019, despite a series of lobbying activities conducted by stakeholders to improve the situation, the government created even more restrictions for the prosumers, e.g. by adding more complex procedures to apply for licensing to utilize the technology and burdening extra operational costs for existing installations.

Knowledge motor that enabled the supporting entrepreneurial movement:

The supporting movement dedicated to PV prosumers in Jakarta, Tangerang and Bekasi City consisted of many small projects related to PV prosumers that were mostly undertaken by households and academic institutions outside Jakarta, Tangerang and Bekasi, (See Figure 6-7). It was moved by various actions that in general were aimed at knowledge sharing and creating recognition for the main entrepreneurial movement. At this level, the motor or engine that enables the supporting movement to work can be categorized as the knowledge motor. The main component of the motor consisted of negotiations among stakeholders that had the goal of creating collaborative projects to support the main entrepreneurial movement. The result of negotiations included agendas, mainly issued by the government, which offered funding possibilities, and direct funding agreements.

For projects such as testing technology at a specific site, or an R&D project which involved public universities and laboratories, the stakeholders required approval either from the incumbent firm or/and from the energy regulator before planning the budget or contacting the potential investors to engage in negotiation. Meanwhile, for activities such as sharing information through seminars or desktop research projects, they firstly existed in the form of meetings among potential involved stakeholders. When the meetings went well, those stakeholders were able to start to collect funding together.

Outcomes from the supporting movement, for example, the most actual information about development or utilization of technology dedicated to PV prosumers, had the potential to indirectly influence stakeholders involved within the main movement. Positive outcomes from sharing information among stakeholders within the supporting movement led to the next round of consolidations or project meetings in the supporting movement itself. If those were successful, then the second round of programs and the second round of funding activities would take place. The new projects that were undertaken in the second round could be a continuity as well as an expansion of the current projects or it could be a totally new project. In contrast, failed projects in supporting movements led to discontinuity of the movement, since it may decrease the interest of the stakeholders to proceed their long-term partnership.

The pilot projects and R&D programs that were categorized as supporting movement for the case of PV prosumers in Jakarta, Bekasi and Tangerang City included the project of smart campus undertaken by BPPT-Puspitek Serpong (2016-ongoing (2018)), and a microgrid project in the industrial area in Cikarang (2018- ongoing (2018)), a smart meter (real-time two-way communication system) in Batam Island (2018- ongoing (2018)) and in Bali Island (2017- ongoing (2018)) (Perusahaan Listrik Negara (PLN) 2017a; Wibisono and Badruzzaman 2018; Arifin 2019c; Perusahaan Listrik Negara (PLN) 2018; Badan Pengkajian dan Penerapan Teknologi (BPPT) 2018). In addition, there were also meeting platforms that were organized by the Smart Grid Indonesia Initiative (PJCI). Sharing information or promotion of the technology through social media, e.g., *Facebook*, internet and *YouTube* were carried out by the stakeholders as well, for example through *Forum Pengguna Surya Atap Indonesia* (Wijiatmoko 2017; Institute for Essential Services Reform (IESR) 2019). The utility and energy policy maker also posted the latest information about the technology on their internet webpage (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2020b).

The outcome of the supporting movement governmentn the case of PV prosumers in the Jakarta, Bekasi and Tangerang City that were beneficial for the stakeholders in the main movement included investment opportunities dedicated to new technology both from national and international counterparts, information about actual government policy to support the technology, and actual innovation/improvement of the technology (for example the complementary software or tools). Urgency of government transparency or the incumbent firm to be fair in facing the current radical innovation as well as up-to date information about PV prosumers standards and its complementary infrastructure were also among the types of common information that could possibly be collected by stakeholders from the supporting movement.

However, the disadvantages of the supporting movement were that many of its projects were time-restricted due to the limited scale of the projects as well as due to the constrained budget (Price Waterhouse Coopers (PWC) 2021; The United States Agency for International Development (USAID) 2019a; Ali et al. 2008; Hermawati and Rosaira 2017). Therefore, it was challenging to make a project in the supporting movement sustainable. In addition, communication and coordination among various small projects was also demanding (Hermawati et al. 2016; Hirsch et al. 2015). Furthemore, the circulated information among stakeholders was rather redundant and partial (Giriantari and Irawati 2016).

6.3.2.3 The role of the incumbent firm in intervening in the adoption of smart meter PV rooftop prosumers

The incumbent firm played a dynamic role regarding PV prosumers in Jakarta, Bekasi and Tangerang City between 2010 and 2019. In the beginning, it welcomed and supported the prosumers, but later it acted more as a part of the political regime that controlled the prosumers. Nevertheless, it increased its awareness about the significance of the technology in society.

From the beginning of 2010 until 2012, the incumbent firm was enthusiastic about the technology and acted as a business partner towards the prosumers. However, as the number of prosumers increased sharply in the following two years, it began to move in a different direction. In 2013, the company issued a regulation as follows (Perusahaan Listrik Indonesia (PLN) 2013): 1). The price of exporting and importing electricity to the grid is solely determined by the utility; 2). The surplus electricity production of prosumers was named as a one-year valid voucher that could not be monetized but it could be used to reduce the import cost for the prosumers for the following months if the prosumers wanted to, and 3). The utility would firstly follow every regulation that was issued by the energy policy maker.

Consequently, after 2013, the incumbent firm gave over all authority of the PV prosumers in Indonesia to the energy policy maker (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2013). Based on this, the incumbent firm started to support the policy maker in it's role as new controller of the technology adopter. They rather curbed the speed of new investment for the technology, but they kept acknowledging the potential benefit of the technology at the same time. This indicated a strong competition between the new technology and the incumbent firm. For example, the incumbent firm agreed with the energy policy maker to exclude the household-prosumers from receiving a Feed in Tariff in 2014 as well as from gaining access to sell the excess of power production using the national ceiling production tariff platform for renewable energy generation in 2017. Furthermore, in 2018, the incumbent firm assisted the energy policy maker to cut the export price of electricity for prosumers up to 35% (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2018c). They argued that the company needed to cover significant grid transmission costs due to more generated power from small intermittent generations that entered the grid. At the end of 2019, the incumbent firm again complied with the mandate of the government to add more detailed administrative requirements for prosumer candidates as well as burden the prosumers with additional safety costs and maintenance of the grid (Indonesian Ministry of Energy and Mineral Resources (IMEMR) 2019d).

In 2015, the incumbent firm issued a smart grid plan to adopt smart grids in Indonesia, specifically for projects that had business relevance to the utility, for example smart metering infrastructure, smart grid management, prepaid electricity systems and on grid-microgrids in rural and remote areas (Perusahaan Listrik Negara (PLN) 2016). However, the implementation of those grand plans were then given to the government (the policy maker for energy) in the following years. This means that the incumbent firm did not desire to guide the PV prosumers directly. Since then, all the business plans related to smart grids that belonged to the incumbent firm were defined and controlled by the government through the policy maker for energy.

Alongside the dynamic condition of the PV prosumers in Indonesia, especially in big cities like Jakarta, Bekasi and Tangerang, the incumbent firm grew its perspective towards the existence of the smart meter for solar Rooftop PV. In the beginning, it wanted to test the compatibility of the PV prosumers in its system. As time went by and the number of prosumers increased rapidly from 2015, it realized the significant benefit of the technology in society but did not deploy simultaneously any measure to support the technology. Having a role as a monopolist in the power sector for more than 55 years, the incumbent firm saw this innovation could be window of opportunity as well as a great enemy (Foster and Rana 2020; Arifin 2021b). A rapid increase in the number of prosumers conceivably led the incumbent firm to face a new radical business change that potentially shifted its position from being monopolist to only a grid operator or even less (Asian Development Bank (ADB) 2016; Hernanda et al. 2018; Arent 2017). The aggregation of PV prosumers was key to reforming the electricity system, from centralistic and fossil fuel dependent to being more decentralized and environmentally sustainable (Institute for Essential Services Reform (IESR) 2019; Lauranti and Djamhari 2017).

6.3.2.4 Learning process done by stakeholders during the adoption of smart meter Rooftop PV prosumers

The learning process within the project indicated that even though the incumbent firm had a strong position to control the diffusion of technology by imposing various measures, the end-users as well as the technology suppliers simultaneously and actively created interactive communication which allowed them to share all information about the technology, thus increase the diffusion and commercialization of the technology. PV prosumers in Jakarta, Bekasi and Tangerang City exhibited active learning through direct experiences when installing and using the smart meter of PV prosumers. They learned by doing and through dealing with failures (Rosyad et al. 2020). In addition, prosumer candidates very much relied on the skills and knowledge about smart meters of PV prosumers from energy consultants to initially carry out their project (Tarigan 2020). In addition, PV prosumers in those cities were active in collecting and sharing information through various channels, for example *Forum Pengguna Surya Atap Indonesia* (Wijiatmoko 2017; Institute for Essential Services Reform (IESR) 2019). They were also involved in particular initiatives from the non-government bodies, the so-called *Asosiasi Energi Surya Indonesia*, to assess a communication channel with the policy maker (Hariyanto 2021; Dewan Energi Nasional Republik Indonesia (DENRI) 2022).

6.4 Discussions: Were cooperation and competition between innovators and the incumbent firm taking place to take the network to the next level?

The results presented in this chapter illustrate smart grid collaborative movements that categorized themselves into a specific innovation hub led by the state-owned utility/monopolist/incumbent firm. Subsequently, those movements showed their own characteristics in the process of building a system of innovation.

In Network 2, the majority of formations and arrangements of resources for collaborative projects were dependent on a small quantity of actors. Based on this, those elite actors defined and monopolized the method of utilization of projects' resources and any possible accumulated or generated outcomes of projects. In addition, other than initiators, stakeholders that were involved to join partnership projects were usually invited by initiators to handle a rather specific task in a specific range of time. Since the organization of the majority of projects within the network were not based on consensus and quite focused on short-term objective, it was likely that in general, the network was still in the early stage of processing to transform as a system of innovation. This illustrated a similarity of findings of the network that was facilitated by the energy policy maker (Network 1), where focal actors dominated the majority of the formations of movements.

In addition, the intervention of the incumbent firm towards its network is in line with the explanation given by Cozzolino et al. (2021) and Pushpananthan & Elmquist (2022). It was aimed at exploring as well as controlling the dynamic of market of the novel technology. Nevertheless, the incumbent firm showed less contribution in creating collaboration platforms within its network than the energy policy maker. It only successfully created less than one fifth of total projects. The energy policy maker, on the other hand, created around one fourth of total projects.

Meanwhile, the main issue for the incumbent firm was not about the dominant role of government, but the significant role of smart grid innovators within the network. Those companies together acted as the biggest creator of partnership projects in Network 2 by creating more than one third of all collaborative movements. Nevertheless, the incumbent firm successfully survived its position in the industry due to protection given by the energy policy maker. The condition can be related to a study done by Geels (2014), Newell (2020), Rechsteiner (2021), and Dallamaggiore et al. (2016), in which, diffusion of renewable energy technologies is conceivably challenged due to the potential coalition between government and the incumbent firm because they may prefer to carefully and deliberately maintain the status quo.

As a general picture, Network 2 depicted an innovation network where actors from different backgrounds were see-able. Innovators, government bodies for technical standardization, and private energy consultants that worked directly with potential technology adopters were visible in the network beside the incumbent firm, energy policy maker, and universities. Regarding activities, the network fulfilled more variative functions of a TIS. It focused not only on basic research and knowledge sharing, but also has a greater number of activities that were dedicated to develop technology at a grass-roots level through on-site pilot projects and independent movements of groups of individuals or communities to introduce the technology. In addition, it presented a significant number of projects that were at changing the current technological regime through active participation of stakeholders in providing inputs during the policy making process. Furthermore, in terms of technology, the network focused more on technologies that can be applied to households. This strategy made the network have a greater portion of projects that were able to handle the novel technology in the form of sellable products, such as smart meters for PV roof-top prosumers, and prototypes that were ready to be tested in the local environment.

In addition, the case of Network 2 shows us about an innovation network for green innovations that were led by an incumbent firm in context of developing countries. In relation to studies done by Cozzolino et al. (2021) and Pushpananthan (2022), category of incumbent firm's intervention towards radical innovation, relationship between the state-owned utility or the incumbent firm and overall stakeholders of Network 2, especially the innovators and early adopters, were in transition between cooperation (first phase) and competition (second phase). At a certain level, there was still cooperation between the incumbent firm and innovators (and early adopters). The incumbent firm aimed at exploring the innovation. It did this through issuing visions related to a novel technology and declaring itself as a supporter of the innovation to earn a new image in the industry, while simultaneously doing the business as usual. In parallel, the innovators and early adopters needed the incumbent firm to get along with their projects, because it helped them to gain legitimacy, licenses for project implementations, access to the existing network of the incumbent firm and ease them to attain co-operation with multiple significant actors in the local electricity sector such as the local affiliations of the incumbent firm, local governments, the energy policy maker, and the focal actors of local electricity business association. Meanwhile, there was an atmosphere of competition or decreasing of trust between incumbent firm and innovators (and early adopters) in dealing with the novel technology. This was started by an incumbent firm that tried to build a potential unfair domination and a lack of transparency with help from the government. This is in line with analysis done by Burke & Stephens (2018), Dallamaggiore et al. (2016), and Geels (2014), where the policy maker and the incumbent firm at some points may be eager to sustain the current technological regime due to either an economic or political reason. In line with research done by Diekhof (2015), Laino (2011), and Reksulak et al. (2008), the chapter showed that the incumbent firm was powerful in terms of both politics and economics. This may create difficulties for new entrants or innovators to enter a more beneficial – mutual relationship, where both of them could co-operate to develop a product together without facing domination from one or both parties.

This chapter took a case of early adoption of smart-meter for residential rooftop PV prosumers in three big cities in Indonesia, including Jakarta, Tangerang, and Bekasi, to illustrate the implementation of TIS in Network 2 in a more specific scope. The results show that in the context of developing countries, the adoption of smart grid technology in those areas was categorized as ''a specific case'' or ''above average case in developing countries'' because the adopters only consisted of high-income households. Nevertheless, the case showed a high potential of adoption of a certain technology if there was any decrease in terms of price of the techno-logy and an easier procedure dictated by the incumbent firm and government to install and utilize the technology. The case of PV prosumers in Jakarta, Bekasi and Tangerang city showed the potential market for the novel technology was the main reason for engaging an entrepreneurial movement. The technology was ready to be commercialized at a large scale, even though experiments and related studies to improve the quality of the product were still on going. The promise of technological encouraged not only potential end-users, but also many private sectors, for example companies which provided consultations and installations. The technology itself was already offered in the market by various local and international vendors. At this level, the technology utilization was easier to be influenced by the fiscal measures issued by the government. The measures, in this case through the determination of the buying and selling of the electricity price set by both government and incumbent firm, conceivably controlled the society to purchase the novel technology and, in the end, determined the price and quantity of the technology in the local market. Only the capacity of the end-users and their network in conducting negotiation or gaining advocacy could influence the government to produce a supportive policy, such as research in campuses and knowledge sharing between adopters.

According to the theory, the entrepreneurial experimentation of smart grid technology in those three cities can be categorized as market niche. This is because the activity is aimed at incentives from the government so that the number of early adopters increases due to availability of fiscal incentives. The lists of actions done by stakeholders created such a motor, the so-called new business motor that aims for marketing the new innovation or beyond know-how sharing. The results are somehow different with previous studies done by Egbetokun et al. (2017), Kebede et al. (2015), and Pillai (2014) which state that most diffusion of renewable energy in poor countries would likely be only about knowledge exploration about the new innovation without presenting any potential creation any of new markets or business models.

Meanwhile, at some points, other findings are in line with research done by Suurs (2009) and Caniels et al. (2007) that state that no matter where it is, as long as innovators are able to conduct lobbyings with politicians and incumbent firms due to significant increase of market of the novel technology, then the innovation motor dedicated to the business of the new technology could be generated. Nevertheless, there were several challenges faced by both innovators and potential end-users in convincing policy maker to support them.

The main engine was the utilization of the novel technology by a limited number of early adopters, in this case households which own on-grid Rooftop PV. The first round of lobbying was done by the early adopters together with innovators from the utility to get allowance to sell the excess generated electricity to the grid. The utility (incumbent firm) started to accept excess electricity from residentials which have PV systems in 2011 but without an explicit rate intervened by the national government (Suyanto 2018). Nevertheless, as the number of prosumers increased dramatically, from less than 100 households in 2011 to more than 1,600 households in 2018, the exact tariff export and import of excess electricity from PV residentials was introduced in 2018 by the government, where the export price was only 65% of import price (Tarigan 2020; Yusuf 2015; Perusahaan Listrik Indonesia (PLN) 2013). In addition, the credit of the prosumers also needed to be subtracted with additional grid maintenance costs that was solely determined by the utility (Pacudan 2017). The increasing number of prosumers using smart meters illustrated the competition between innovators and the incumbent firm to stay in business. To survive, the incumbent firm tended to stay under support of the government.

The resistance of the incumbent firm towards the novel technology was due to the possible creation of a new business model that might destroy its vertical supply chain. This has already happened in Vietnam, where private PV prosumers are connected together by an aggregator which acts as an intermediate between them and the electricity market (Arifin 2021a). At this level, the electricity monopolist potentially loses its power in the controlling market (Akhmad et al. 2017).

6.5 Summary

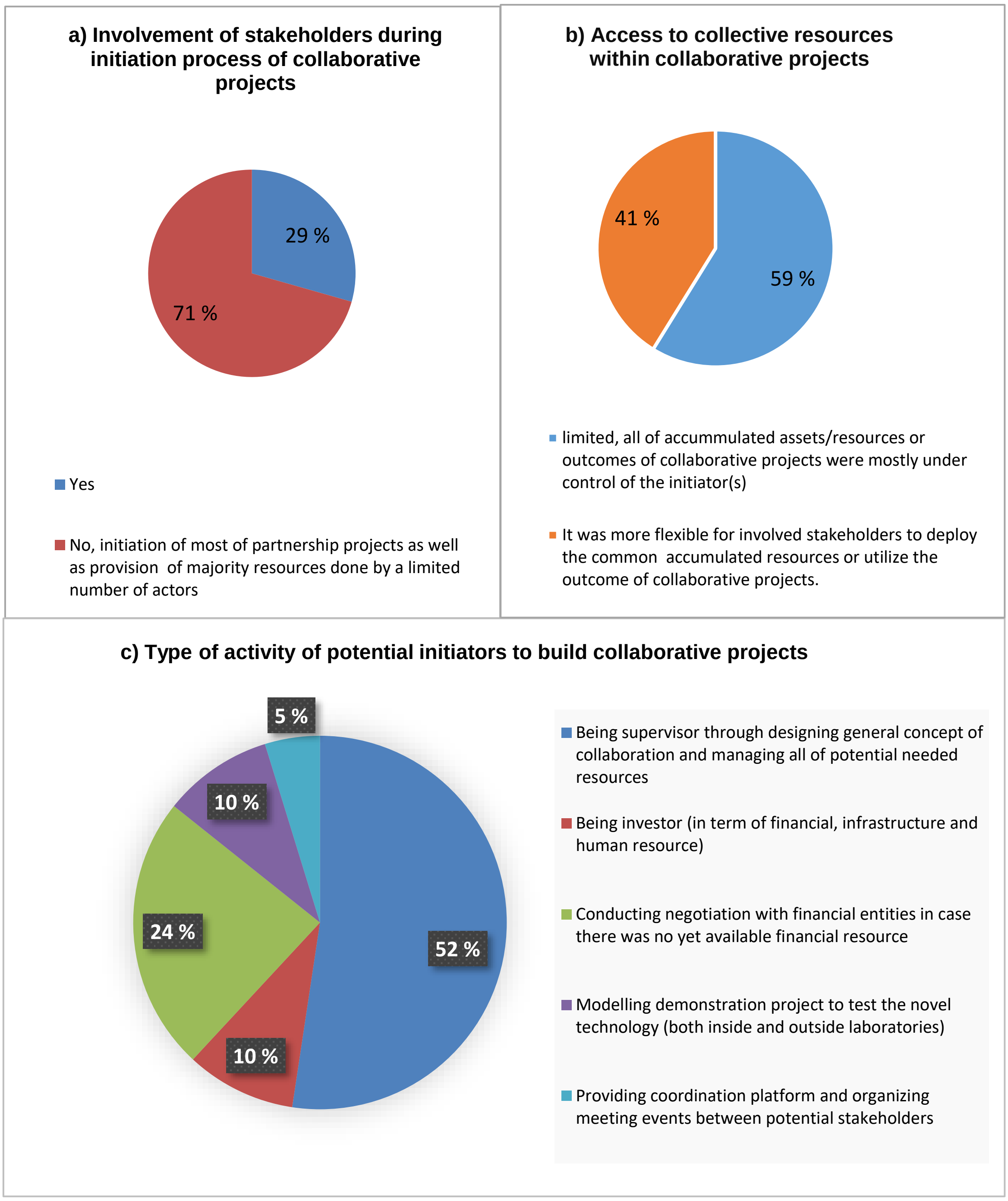
The chapter demonstrates that, in general, Network 2 was still in the early phase of its process in growing up into a system of innovation due to use of the dominant network resource orchestration in the majority of collaborative projects and the dominant role of the incumbent firm with help from the energy regulator in controlling the network. Nevertheless, the network, at some points, showed its potential to grow into a technological innovation system (TIS), for example through its capacity to implement more systemic functions outside basic research and knowledge sharing, the active contribution of early adopters in creating legitimacy for the novel technology and the potential competition between the incumbent firm and innovators.

7 Case 3: The Innovation network for smart grid technologies in Indonesia guided by the research and higher education policy maker (The Network 3)

This chapter depicts the progress of an informal innovation network mainly guided by the Indonesian Ministry of Research and Higher Education in introducing, developing and commercializing smart grids in Indonesia between 2009 and 2019. A detailed investigation about resource management of the network, intervention of leading actors in influencing members of the network and performance of the network in implementing functions of a system of innovation are presented.

7.1 Resource network orchestration: between domination of a limited number of players and more opportunities to enjoy the accumulated resources of projects together

The results shows that more than 70% of total collaborative projects were created or facilitated by a limited number of actors (See Figure 7-1). Nevertheless, the network showed that more than 40% of stakeholders argued that they were able to enjoy the accumulated asset generated as well as the outcomes created together through their collaborative activities. Meanwhile, from almost one third of stakeholders that were potentials to act as initiators reported that they created co-operation projects within Network 3 through different methods. In line with conditions within Network 1 and Network 2, most projects within Network 3 were built by at least two main initiators that basically provided the funding and concept of projects. In addition, most initiators had their own specialization in building their collaborative arrangements. Most of them started to generate projects by proposing a general design of projects to their potential partners (52%). At the same time, around 24% of potential project builders argued that they need to lobby the investors first before contacting their project executors. Furthermore, there was 5% of total potential project creators building their collaborative projects by engaging meetings or consolidations with other potential stakeholders first. The findings also indicate that only 10% of collaborative project creators within he Network 3 started to build their partnership projects by working as resource provider or specifically offered models of demonstration projects for the novel technology to their potential project partners. An interesting finding is that in Network 3, there were no initiators of projects that started collaboration projects by introducing their technology prototype. This means there was lack of interest for smart grid companies or related private firms to primarily initiate coope-rative arrangements within Network 3 during the period 2009-2019.



Source: Own Depiction

Figure 7-1 Characteristics of resource orchestration applied in collaborative projects within network 3 (2009-2019)

Consistent with the results from the on-line survey regarding the initiation process of collaborative projects, the expert-informants from Network 3 also stated that activities relating to smart grids in Indonesia within the academic domain had a high dependency on a limited number of actors that could provide stakeholders programs or funding possibilities. Nevertheless, Network 3 showed potential enthusiasm in implementing independent movements undertaken by a group of individuals or private communities in introducing smart grid technologies through mass-media because there were less costly.

''In my opinion, the quantity of collaborative movements for smart grid done by universities had a high correlation with (number) programs from government. Because from those programs, we (universities) got funding access." (Interviewee Nr. 11).

''Universities or research centres in Indonesia mostly faced problems in funding their projects sustainably. The problem was also faced by research projects related to smart grid technologies. Funding programs from the government or from international partners were our main resource, but they were very dynamic. Changes in terms of the economic and political situation might influence the characteristics of the funding." (Interviewee Nr. 10).

'' Beside research activities that still had a high dependency on financial supports from the government, I think at a grass-roots level, there were many independent projects for sharing knowledge that were implemented by scholars using free on-line forums or blogs or social media." (Interviewee Nr. 12).

In addition, a higher proportion of projects that provided a more flexible access for the involved stakeholders in utilizing projects' resources and outcomes within the Network 3 was conceivably taken place due to a high portion of activities that were aimed at sharing information. In those activities, accumulated assets within projects, for example in the form of contacts or materials, were mostly easy to be used or circulated to a limited range of stakeholders.

''For projects that were aimed at sharing knowledge, there was usually an agreement that most of the information or know-how provided by those events can be utilized or circulated by individuals or communities in a more flexible way. Most of the information was shared between academics or policy makers." (Interviewee Nr. 9).

''Information about smart grid technologies derived from classes, seminars, and sharing platforms were usually free to be shared by stakeholders. However, circulation or utilization or ownership of knowledge or resources generated through specific research projects or experimentations depended on the initiators or main funders." (Interviewee Nr. 10).

''During implementation of projects for sharing knowledge, it was usually easy for involved stakeholders to utilize the resources gained through projects, for example contacts or links with new potential project partners." (Interviewee Nr. 12).

7.2 Intervention of the research and higher education regulator in its network: The one with big potential but weak resources

7.2.1 Research and higher education regulator had the biggest potentials to influence its network

Figure 7-2 represents the average potential of each actor in Network 3 through scores of social network indices, including degree of centrality, closeness centrality and betweenness centrality. In general, Network 3 had a quite low average value of social network indices (0.22) for its stakeholders. In addition, Network 3 had an average score of closeness centrality of all stakeholders (0.30). It was greater than its average score of degree centrality (0.22) and average score of betweenness centrality (0.14). This trend was equivalent to what happened to Network 1 and Network 2, where activities for engaging contact through sharing information was rather easier to do than actions to initiate or to encourage project collaborations between stakeholders. Even though the magnitude for those three activities in those networks was considerably low.

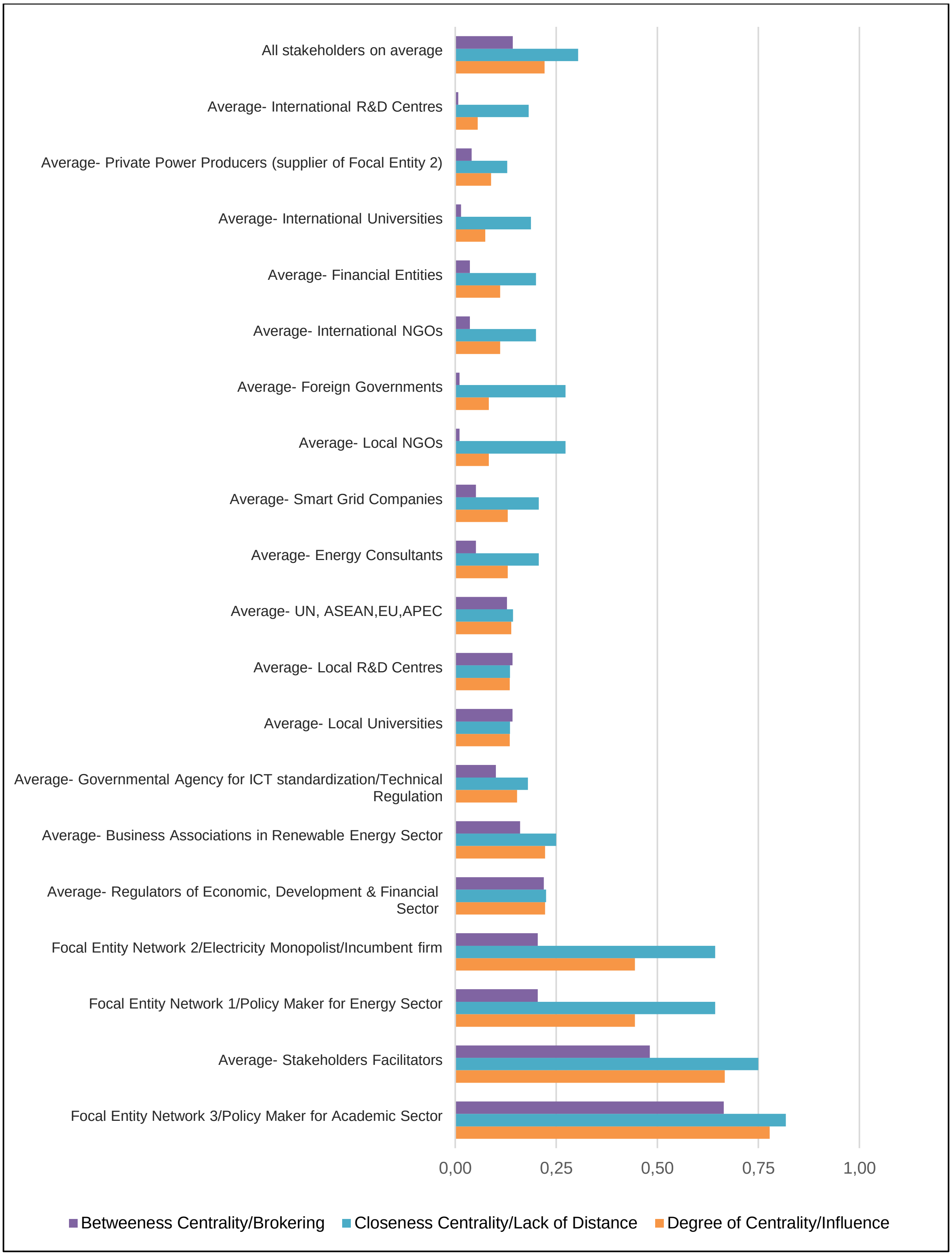
The policy maker for research and"governmentig'er education sector was unveiled to be the stakeholder that had the highest value of social network indices of 0.75. It demonstrated the potential ability of the entity to be the most important actor within the network. It had a significant possibility to circulate and acquire information among stakeholders since it had a high value of closeness centrality index (0.82). Activities to coordinate other stakeholders were also among its potential skills since its centrality index was 0.75. At the same time, it was likely the most capable actor in Network 3 that could build a collaborative environment among stakeholders because its betweenness centrality index could reach 0.66 point.

Subsequently, stakeholder facilitators were listed as the second potential actor within Network 3. Their average value of social network indices of 0.67. They had significant possibility to bring together most of all stakeholders, to circulate information as well as to enhance collaboration among stakeholders. Other actors that also had a conceivable essential role in Network 3 were the energy policy maker and the incumbent firm. Despite their a quite low level of average betweenness centrality (0.20) and closeness centrality (0.43), those organizations showed a significant level of centrality index to level 0.64. This means that even though both of them did not have a huge potential to enhance collaboration between stakeholders within Network 3, they had a chance to influence the network through diffusing as well as absorbing any kind of information from the academic realm, for example about political, financial and technical regulations related to smart grids.

Meanwhile, Figure 7-2 shows the average social network index of local universities and local research centres was significantly low (0.17). This indicated that as a single organization, most of the academic and research entities did not have a strong potential to influence other stakeholders within the network. This condition was also argued by expert-informants. Its explained that among many academic organizations, there was only small number of those which had significant capacity to build or engage their own collaborative projects.

''Most universities and research centres were keen on studying the most actual situation of smart grids in Indonesia as well as in the world. The quantity of individuals, e.g. scholars who had interest in sharing the future potential of the technology to society, were big as well. However, as a single organization, most of them had a limited capacity to enhance or to influence the innovation network for smart grids (at national level) due to a short supply of financial, expertise and political power.'' (Interviewee Nr. 11).

''Not all universities or reserch centers already had networks, infrastructure, specifically laboratories, or funding or expertise about smart grid technologies. Usually we (universities and research centres) collaborated with each other." (Interviewee Nr. 10).



Source: Own Depiction

Figure 7-2 Different value of social network indices between different groups of stakeholders of Network 3 (2009-2019)

7.2.2 The research and higher education policy maker was empirically less powerful than universities, the energy policy maker, and the incumbent firm in operating its own network

7.2.2.1 Small contributions in creating collaboration platforms among stakeholders

In Network 3, despite having the highest potential in enhancing collaborations between stakeholders within Network 3, the research and higher education policy maker did not act as the main collaboration initiator for smart grid activities for that period. According to the result of the on-line survey, it contributed to create only around 15% of total collaboration arrangements. At first, the condition depicted a contradiction with the result of social network analysis, which mentioned that the policy maker had a significant likelihood to influence the network based on its scope of contacts with other stakeholders. Nevertheless, the actual condition in the field gave a deeper explanation about the result of analysis, especially related to the character of the relationship between the research and higher education policy maker itself and its stakeholders within the network.

For more details, the research and higher education regulator had quite limited resources, e.g. a limited financial capacity in handling smart grid activities which then influenced its performance in bringing together other stakeholders. According to expert-informants, the research and higher education regulator did not have a strong coordination channel with the financial ministry in order to open up the possibility to develop more significant funding schemes for research activities, e.g., for smart grid movements. The organization also did not have authority to directly contact and create agreement with other potential financial entities, especially international donors, to enhance any new funding scheme for diffusion of smart grid technologies. The financial ministry under coordination with the policy maker of the energy and electricity monopolist had the authority to do that. On the other hand, the energy policy maker and the electricity monopolist already had their own priority or agenda towards smart grids. Consequently, any kind of funding opportunities generated under coordination of those two entities would likely be firstly deployed to facilitate activities initiated within their own nexus.

At the same time, due to its position as ministry non department or ministry that did not lead a specific sector (note that in Indonesia, the academic sector was already managed by the ministry of basic education and culture, not by the ministry of research and higher education), the research and higher education regulator did not have a direct two-way communication to discuss any new smart grid programs with other government bodies or state-owned companies, e.g., financial ministry, energy and resource ministry, and electricity monopolist, without agreement from the president or at least ministry of interior. Therefore, there was always a chance of delays in process of communication and coordination between the research and higher education regulator and other ministries in the cabinet. Between 2009 and 2019, the research and higher education regulator was also highly dependent on budget scheme approval by the finance ministry and the president in order to issue funding opportunities and organize research activities among universities and research centres every year. This condition depicted that the entity did not have authority to decide its own financial plan.

Meanwhile, the electricity monopolist succeeded in becoming the founder of 23% of total collaborations within Network 3. The energy regulator produced 15% of total projects as well. This is in line with the result based on social network analysis, where the incumbent and the energy policy maker were among influential orga-nizations within Network 3. Furthermore, stakeholder facilitators successfully created around 8% of total cooperation projects. It was argued by the expert-informants that stakeholder facilitators, e.g. the national smart grid initiative, had support from the government, including the state-owned utility, that made them able to initiate a negligible amount of cooperation among stakeholders within Network 3.

''The research and higher education regulator might have the ability to influence the national research planning, but it had limited capacity to provide sustainable support, especially financial support. In contrast, organization, such as the Indonesian Smart Grid Initiative, which had strong links with the utility, could unite all actors from universities and R&D centres to engage in national meetings and seminars regularly. Beside strong connections with the utility, it had significant links with many potential stakeholders from industry and international counterparts. It was of course very beneficial to take a part in events that were organized by it.'' (Interviewee Nr. 9).

'' We could not deny that the electricity monopolist and the government (energy regulator) had a significant influence on them (smart grid networks or movements in Indonesia). They produced regulations for smart grids that would impact activities in academics, either in a direct or indirect way. For example, when the ministry of energy and mineral resource campaigned for potential smart grid applications in rural areas, it indeed enhanced a series of discussions as well as funding opportunities to create eagerness of research centres to be involved in such a project, especially in the eastern region of Indonesia.'' (Interviewee Nr. 12).

Another relevant finding is that between 2009-2019, there was no project within Network 3 that was firstly proposed by private companies, NGOs, local communities, or international partners. Subsequently the result of the on-line survey illustrates that academic and research entities were supposed to initially propose 35% of total collaborative projects. According to expert-informants, there was only a limited number of research centres that could implement their smart-grid projects autonomously. Therefore, a high percentage of projects initiated by universities or research-centres were conceivably due to the procedures of getting annual fundings from central government, in which they had to issue research proposals first and then discussed them with government, especially with the ministry of finance.

‘’ Each public university and research centre in Indonesia got annual funding from the finance ministry to implement their research project. Usually the scheme covered desktop research projects or seminars. To get the money, we needed to send the proposal first.” (Interviewee Nr. 12).

‘’ Each year we (public research institute) usualy submitted a proposal to the ministry of finance in order to receive annual research funding. We were free to decide the topic of the research.” (Interviewee Nr. 10).

7.2.2.2 Staying positive through giving research guidance despite its limited resources

Disclosing regular research guidance

In 2004, the the research and higher education regulator issued the Long-Term National Research Plan 2005-2025 (Indonesian Ministry of Research and Higher Education (IMRHE) 2004). In the document, the organization focused on five priority sectors, including drugs and health, food security, defense, information and communication technology, and renewable energy. However, the plan did not specifically explain the grand design or a long-term milestone for research and development in the renewable energy sector. It only gave the general description about the names of groups of technologies that should be developed or introduced in Indonesia. Research activities related to hybrid systems based on renewable energy and its supporting technologies were among the list of topics that would be funded by the government.

After five years, the research and higher education regulator issued a short-term national research plan for the period 2010-2014 (Indonesian Ministry of Research and Higher Education (IMRHE) 2010a). For that period, smart controllesr for hybrid power plants and microgrid technology were explicitly mentioned as significant topics. Funding programs for those topics were also organized by the Research and Higher Education Regulator. A short-term national research plan 2016-2019 together with funding programs were also issued in 2015 (Indonesian Ministry of Research and Higher Education (IMRHE) 2015). Smart grids were clearly introduced in the plan. In addition, the research and higher education policy maker stated a series of goals for those periods, including prototypes of decentralized smart microgrids, prototypes of a series of demand control systems for building offices, campuses and industrial park, and the establishment of a research consortium for electric vehicles. Furthermore, the leading stakeholders for smart grid innovation, including the energy regulator, the state-owned company for ICT (PT LEN), Indonesian Ministry of Communication and Information, and the BPPT were also mentioned in the document as the main actors to be interconnected under the programs that were organized by the research and higher education policy maker. Nevertheless, the document did not explicitly mentione the incumbent firm as one of the main involved stakeholders. This conceivably indicated a rather weak or indirect interrelationship between the academic domain and the industry in processing the national research planning.

In 2017, the policy maker disclosed a long-term national research plan for the period 2017-2045 (Indonesian Ministry of Research and Higher Education (IMRHE) 2017). The document stated that for the time being, the national short research plan for the period 2016-2019 would also be the goal for Indonesia for the time period between 2017 and 2045. In addition, in the process of preparing and implementing the plan, the research and higher education policy maker changed its strategy from a top-down approach to a mix between a top-down approach and a bottom-up approach. This meant that stakeholders were involved in the formulation of goals as well as technology priority in the renewable energy sector. Based on the strategy, the research and higher education policy maker had the authority to mention the research grant topics and the funding capacity of the entity to be deployed. The stakeholders, on the other hand, were welcomed to send in their research proposals. In the period, the entity started to link its program with industry by enhancing coordination with the Indonesian ministry of industry. This policy was in line with the previous finding, where the academic organizations were required to send their initiations in the form of a project proposal first, before they got the funding.

Problems in terms of resources and coordination

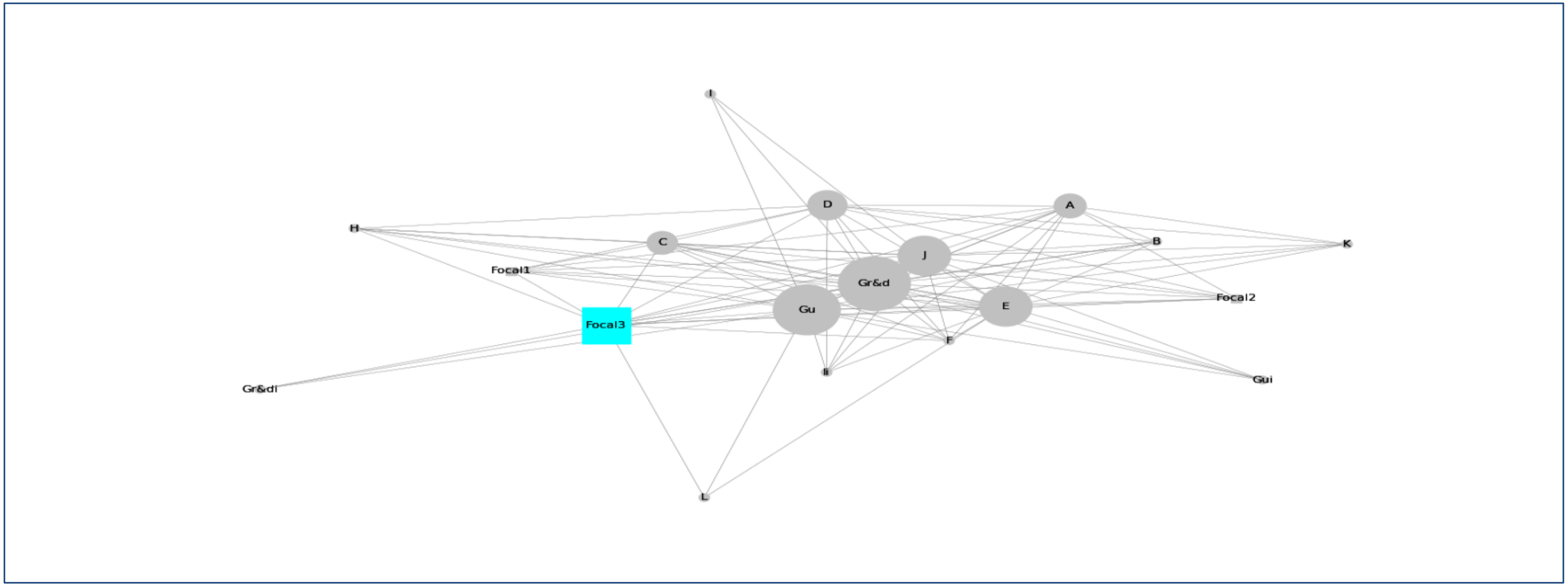
Nevertheless, limited resources and a weak connection with other government organizations were also challenges met by the research and higher education regulator in convincing its plan. For example, due to the limited number of internal experts, the office of the entity was highly dependent on inputs or proposals from universities in order to create and implement its incoming plan and annual budget (Huda et al. 2020). In addition, a lack and weak coordination with the energy regulator as well as with the electricity monopolist due to its lower hierarchical position within the cabinet structure resulted in challenges for the entity to accelerate its smart grid movements with the same movements belonging to those bodies (Rakhmani and Siregar Fajri 2016). In the end, it potentially produced a redundancy of activities as well as a situation where universities and research centres preferred to be connected directly to other organizations which had more power to provide funding possibilities and long-term research milestones., e.g. energy regulator or electricity monopolist, than with the entity.

7.3 Performance of the network in implementing functions of a technological innovation system (TIS) of smart grid technologies: It was more about universities and basic research

7.3.1 Performance at a macro level through collective - collaborative actions

7.3.1.1 The majority actors were from the academic domain

Network 3 embraced 19 types of different organizations connected to each other while undertaking smart grid projects between 2009 and 2019. According to the number of links that the stakeholders owned, there were five types of organizations that had the highest level of interconnectedness within the network. Those type of organizations were local R&D centers, local universities, the regulators for economic - development and finance sector, supra-national organization, and the research and higher education policy maker. In Figure 7-3, it can be seen that even in its own network, the research and higher education policy maker was not at the center of the network which conceivably indicated the limited capacity of the entity to lead or be main player of the network. Meanwhile, local R&D centers and universities and international counterparts, such as the UN, ASEAN, EU and APEC had potentially been pivotal actors of the network. Furthermore, the size of each type of organization that was generated based on the distribution of experts which participated in the on-line survey, shows that local R&D centers, local universities, and the research and higher education policy maker contributed to the majority of the population. Other types of organizations that also had a significant size within Network 3 included the regulators for economic-development, the financial sector and supra national orga-nizations.



Code	Description	Code	Description	Code	Description	Code	Description
A	Business Association in Renewable Energy Sector	**F**	Private Power Producers (supplier of Focal Entity Network 2/Monopolist)	**H**	Smart Grid Companies	**K**	Financial Entities
B	Energy Consultants	**Gu**	Local Universities	**I**	Local NGOs	**L**	Foreign Governments
C	Governmental Agency for ICT standardization/Technical Regulation	**Gr&d**	Local R&D Centres	**Ii**	Int' NGOs	**Focal 1**	Focal Entity Network 1/Policy Maker for Energy Sector
D	Stakeholders Facilitator	**Gui**	Int' Universities	**J**	UN, ASEAN,EU,APEC	**Focal 2**	Focal Entity Network 2/Utility-Monopolist
E	Regulators of Economic, Development & Financial Sector	**Gr&di**	Int' R&D Centres			**Focal 3**	Focal Entity Network 3/Policy Maker for Education/R&D

Source: Own Depiction

Figure 7-3 Feature of connectedness among different groups of stakeholders within Network 3 (2009-2019)

7.3.1.2 Basic science dominated collaborative projects

Figure 7-4 illustrates that Network 3 dedicated around 78% of its collaborative projects to implement knowledge sharing and basic research located on campuses. In addition, there was a noticeable but quite small number of activities that were carried out at grass-roots levels, including activities of sharing knowledge done by groups of individuals (9%), and product consultations led to demonstrate projects (2%). Meanwhile, the network illustrated that movements for smart grid technologies at regime level were not its main goal. It was represented through a low percentage of macro-scale activities within the network, including national/local work groups for proposing fiscal incentives (5%), national/local committees to recommend technical regulation (5%) and meetings led to lobby (1%).

This is in line with the data from expert- informants. They argued that the main objective of stakeholders within the Network 3 was to earn publications and share know-how amongst themselves. In addition, the limited capacity in terms of technical expertise as well as links with the incumbent firm or the energy policy maker made them difficult to participate in nation-wide programs.

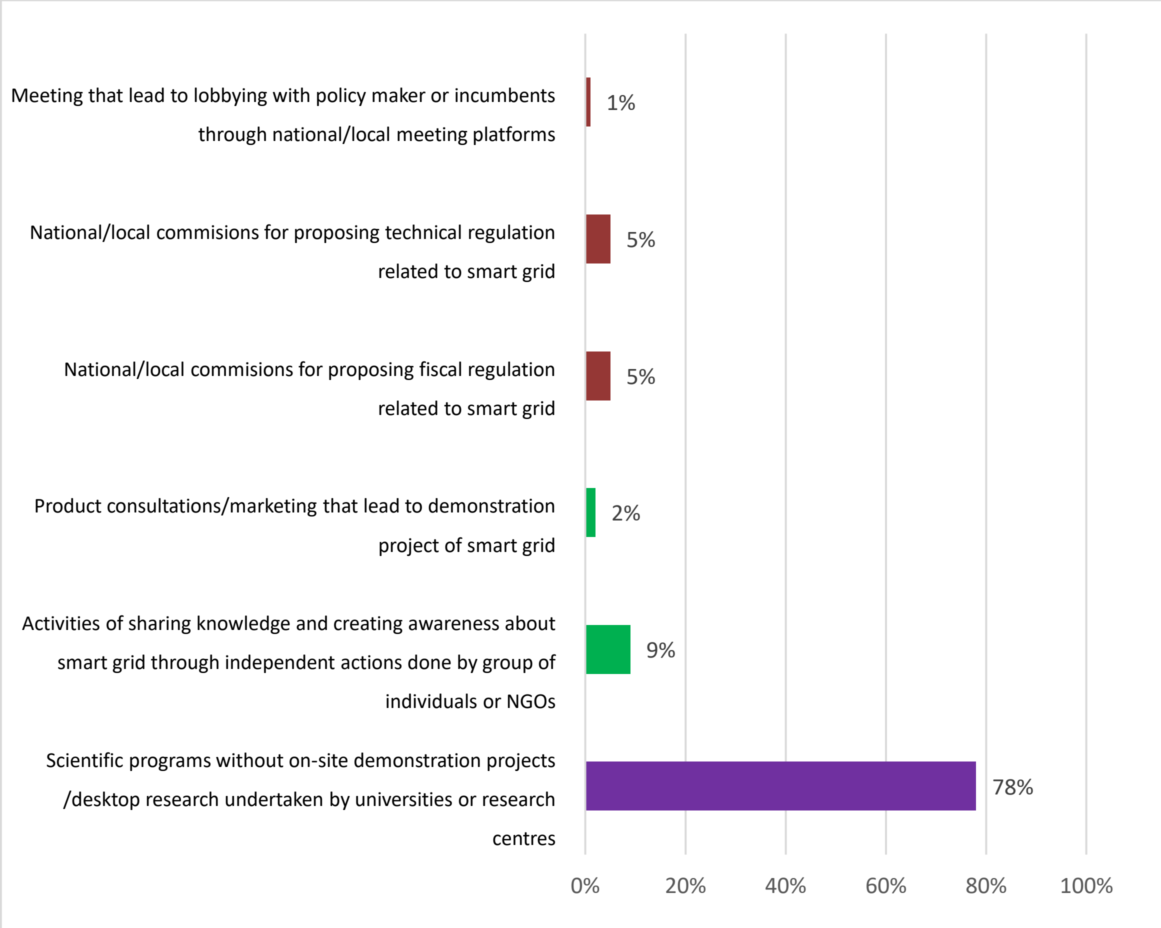
'' Universities and research centres in Indonesia already had a huge interest in smart grids. They discussed, talked, and researched about smart grids since around 2013. However, most of the results were papers for class presentations and publications but not at level of a ready to use technology.''(Interviewee Nr. 11).

'' Publications and seminars were among the main outcomes of smart grid movements within the academic domain. Many scholars also have a passion to share their know-how independently in different platforms, for example through their blogs or particular forums of renewable energy'' (Interviewee Nr. 10).

''Only public research centre or public university that had contact either with the energy policy maker or with the incumbent firm that could have access to either engage in a national team for preparing national policy or to be involved in a nation-wide smart grid on-site project. The BPPT was among them.'' (Interviewee Nr. 8)

'' A small number of well-known and experienced public research organizations or univerisites that had a good relationship with both the energy policy maker and the electricity monopolist usually already had numerous experts related to renewable energy and a permanent research facility that enhanced them to install and test the technology rather easily on its facility.'' (Interviewee Nr. 9)

''Direct contact between universities and industry, in this case smart grid companies, very seldom happened. Usually those companies preferred to engage cooperation with the incumbent firm or the energy policy maker in order to implement their on-site pilot projects. Only public universities or public research centres that had close links with government may be invited to join the co-operation.'' (Interviewee Nr. 12)



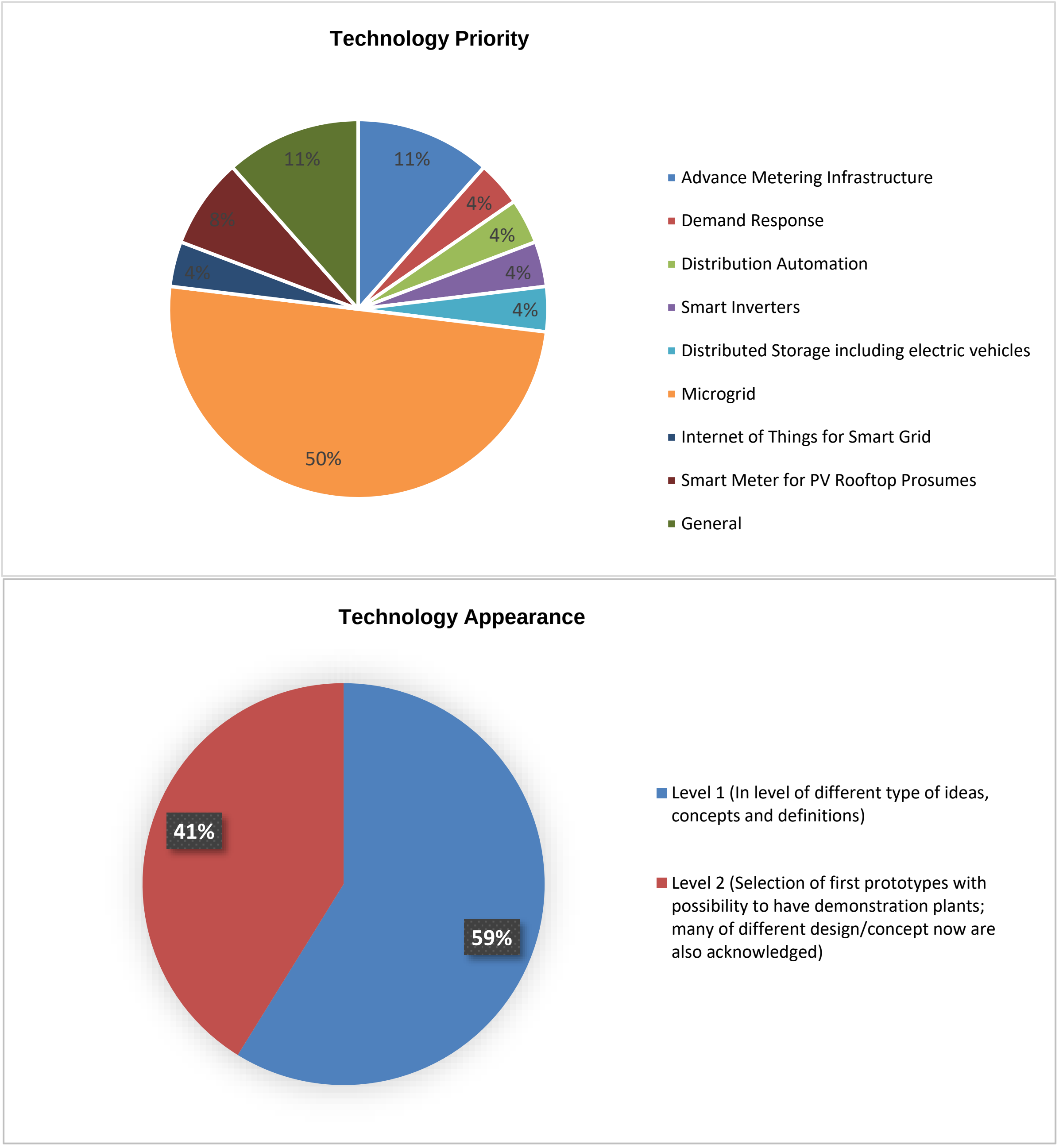
Source: Own Depiction

Figure 7-4 Collective activities to implement functions of TIS within Network 3 (2009-2019)

7.3.1.3 The appearance of technology was more in the form of ideas and concepts than in form of prototypes

More than half of the collaborative projects within Network 3 concentrated on smart grid technologies that was aimed at decentralized power systems and renewable energy penetration, including smart microgrid (50%), distributed automation (4%), smart inverters (4%), internet of things (4%) and distributed storage including electric vehicle (4%) (See Figure 7-5). This is in line with the research plan disclosed by the research and higher education policy maker. Meanwhile smart meter applications were handled in around 19% of total projects. In addition, there were also around 11% of total projects that spoke about smart grid technologies in general.

Based on the appearance of technology, there was almost 60% of projecst that took care of smart grid technologies in the form of ideas, concepts and definitions. Meanwhile, around 40% of projects handled the prototype of the novel technology. To sum up, those conditions are in line with most of the activities of Network 3 that focused on scientific evenst within the academic domain where the smart grid technologies were conceivably explored or examined with less direct contact with end-users.



Source: Own Depiction

Figure 7-5 Technology priority and technology appearance in collaboration platforms within network 3 (2009-2019)

Meanwhile, according to expert-informants, the high share of projects in the academic domain that still handled theories of smart grids were very much due to the majority of academic institutions in Indonesia that still focused on teaching. In addition, a lack of sustainable funding and compatible infrastructure potentially led academic insitutions, especially schools or colleges, to dedicate their movements to only desktop research projects.

''We should differentiate between universities and research centres. Universities gave more attention to teaching and seminars, whereas research centres were busy conducting research activities only. That was why, they (universities and research centres) had different type of financial plan and capacity in having a more reliable or permanent research infrastructure that was compatible with smart grids. Usually, movements done by research centres were lasting longer than those done by universities because of those factors (focus, financial and research infrastructure).'' (Interviewee Nr. 9).

''Most academic insitutions in Indonesia focused on teaching and desktop research. Only a limited number of universities and research centres dedicated themselves to handling renewable energy innovation in the form of on-site pilot projects. Because it usually needed a more specific infrastructure, expertise and additional money.'' (Interviewee Nr. 10).

''It was difficult for us to handle specimens of the novel technology by ourselves. For example, we were installing it because we got funding from the government, but after the funding ended, it became challenging because we lacked focus (because of teaching and our other incoming projects) and lacked funding to maintain the installation. That was why we (universities) preferred to do teaching and knowledge sharing only.''(Interviewee Nr. 11).

7.3.2 Performance at a micro level through entrepreneurial experimentations: The case of a Smart microgrid project in Baron Techno Park

7.3.2.1 Background and project specification

The smart microgrid project in Baron Techno Park was one of the on-site pilot projects undertaken by academic organizations within Network 3. It reproduced the model of smart microgrid projects that had already been carried out in the Puspiptek Campus in Serpong, Banten Province. The Baron Techno Park itself was located in Kanigoro Village, Saptosari District, Gunungkidul Regency, Yogyakarta Province. It was about 55 km from the Yogyakarta City, the capital city of Yogyakarta Province. This area was designed by the local government to be a permanent facility for renewable energy studies dedicated to rural areas around central Java region as well as a place for information dissemination regarding renewable energy technologies.

The funding for the Baron Techno Park development came firstly from The Norwegian Agency for Development Cooperation (Norad) as a grant in 2009, this amounted to NOK 6.5 million or equivalent to US $ 1.18 million (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2015). The project also gained significant monetary and legal support from the local government of district Gunung Kidul and Yogyakarta Province in the following year (Jarwadi 2016). It was then integrated as the part of the Agro Techno Park and Baron Beach facility in 2009 (Giyanto 2015). In the same year, the local government decided to provide authority to the *Badan Pengkajian dan Penerapan Teknologi* / Agency for Assessment and Application of Technology (BPPT) as the daily operator of the techno park (Prastawa et al. 2017).

In 2010, the Techno Park undertook a hybrid power plant construction project. The power plant generated electricity by using a combination of 36 kWp mono-crystalline PV modules produced by PT *LEN Industri* and 2 wind turbines, one had capacity of 10 kWp and the other one had capacity of 5 kWp (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2016). These two intermittent sources were then used to cover the loads in the vicinity surrounding the power plant along with a battery bank with a total capacity of 1000Ah that supplied 240 kWh/day and a 25kVA diesel generator (Djamin et al. 2012). The construction of the hybrid power plant was completed in 2012 (Suhartanto 2014). Furthermore, a hybrid power controller, 25 Kva of a system data acquisition and a weather station were added to the power plant in the very same year (Pae et al. 2017).

Besides conducting research and development related to renewable energy, the techno park was actively open to potential stakeholders to be visited. It was also open as a regular destination for scientific tours or the so-called ‘’Safari knowledge’’ for students in Indonesia. In 2016, it was officially open to the public (Widhyharto 2018). In the following year, it started to organize an annual scientific competition for junior and high school students in Indonesia (Prastawa et al. 2017). Furthermore, science festivals and exhibitions were also organized regularly in the techno park (Gravatar 2020). Those strategies were able to generate income as well as to provide feedback for the development of the techno park itself.

Subsequently, the techno park carried out a replication of the Puspiptek-Serpong smart microgrid in 2018. The project basically consisted of a smart controller for hybrid power generation- off grid and a smart meter for the export/import of electricity between the techno park and the utility. The system had a specification as follows (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2016):

- For smart meter on grid: Rooftop PV subsystems (1 unit) with total capacity 15 kW p- on grid
- For smart controller for hybrid power plant:
    - A 10 kWp capacity solar photovoltaic (PV) rooftop system with smart microgrid technology. This was installed on the top of the Energy Building within the area of Baron Techno Park.
    - This system started to operate in December 2017.
    - Rooftop PV was integrated to the grid electricity using the on-grid inverter of SMA Sunny Tripower TL10000 with a capacity of 10,25KW.
    - This system is equipped with 2×5 kWh Li-ion battery with Hybrid Inverter Sunny Island SI3.0M and supported by SCADA (Supervisory Control and Data Acquisition) System and Weather Station.

a) Map showing Location of Smart Microgrid Project in Baron Techno Park, Yogyakarta Province
Source: (Tataruang 2022)

b) Photos of gate, monitor building, wind power plant, PV power plant, and example of fuelcell station within Baron Techno Park

Source: (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2015, 2016; Giyanto 2015; Jarwadi 2016)

Figure 7-6 Map of location and parts of installation of smart microgrid in Baron Techno Park

7.3.2.2 General characteristics of the microgrid project in Baron Techno Park

<u>It was a replication of previous related projects done by academics</u>

The smart grid microgrid project in Baron Techno Park was correlated to a similar project undertaken in Pupiptek Serpong Campus. Both of those projects were run and managed by the BPPT. Installation of microgrid system in Baron Techno Park took place in 2018 or after a task for installing a smart microgrid in Puspiptek-Serpong was successfully completed. The description about the project drawn in Figure 7-7 is as follows:

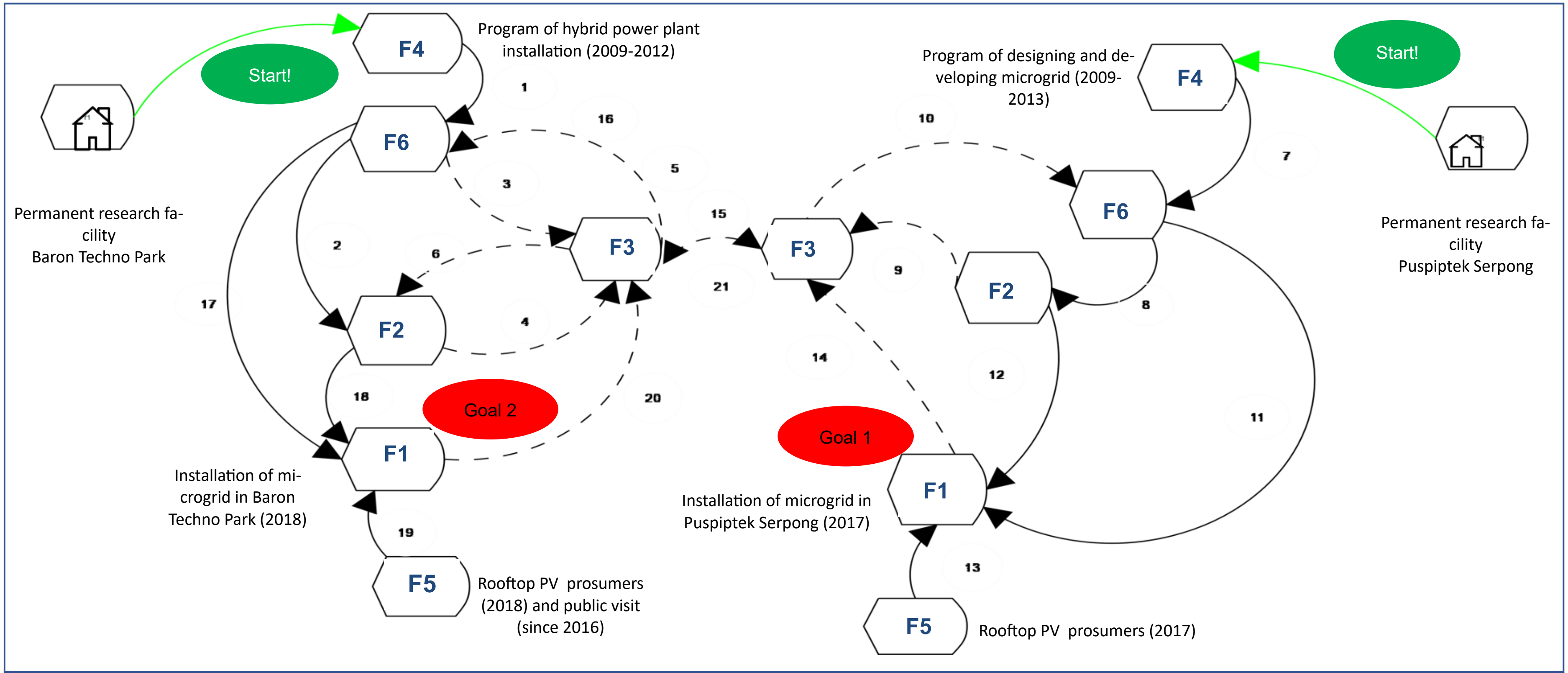
- There is a solid line that is drawn between each permanent facility, in this case Baron Techno Park and Puspiptek Serpong campus, and its program.
- Each smart grid microgrid project was a continuation or expansion from a previous program belonging to each facility. The smart grid microgrid in Serpong was a continuation from the smart grid design and development program, whereas the smart grid microgrid in Baron Techno Park was an expansion of the hybrid power plant program.
- The engine of the demonstration project of the microgrid in Baron Techno Park consisted of a variety of activities. These included the creation of programs, program funding, R&D activities, knowledge sharing, and income generation. The same activities were also undertaken by the involved actors in the microgrid project of Puspiptek Serpong.
- Dotted lines between activities showed indirect or rather delicate correlations between actions done by actors in the demonstration projects.
- Each program from each facility generated its own knowledge sharing activity. The program implemented by the Baron Techno Park mainly involved local stakeholders, such as the local government of Yogyakarta, local universities as well as communities. On the other hand, the programs implemented by the Puspiptek campus was at a national level and involved funding from the central government, the research and higher education regulator, as well as the electricity monopolist.
- There was a delicate reciprocal relationship between two knowledge sharing activities derived from the program managed by Baron Techno Park and from the program under supervision of Puspiptek Serpong. The relationship between the two groups of knowledge sharing activities was the main factor which was able to connect the two programs. It also had the greatest potential factor for a replication project, in this case the installation of microgrid technology in Baron Techno Park that copied the configuration of the microgrid project in Puspiptek Serpong.

Activities to install a microgrid in Puspiptek Serpong that inspired stakeholders to initiate a microgrid project in Baron Techno Park

The program for designing the smart microgrid in Puspiptek Campus took place between 2009 and 2013 (Oktaufik und Prastawa 2014). The costs of the program were covered by the annual funding scheme dedicated to public research centres that came from the Indonesian Ministry of Finance. The master plan for smart grids in Puspiptek Campus-Serpong was one of the important outcomes of the program. The designing activities were then followed with sharing knowledge activities between the BPPT and its stakeholders. However, these activities were carried out independently by the BPPT or without any significant external funding. The dotted line between the research and the knowledge sharing activities in the program represents the limited capacity of the program to influence stakeholders, due to its constrained resources to connect purposefully to a broader range of stakeholders. On the other hand, the feedback from the majority of stakeholders was also not able to be directly implemented or responded to by the BPPT because of restricted resources.

In 2017, the Indonesian Ministry of Finance agreed to finance the implementation of a smart microgrid within public research facilities. The target included the installation of at least 100 kWp solar photovoltaic in Serpong Campus, Serpong, Banten Province within 10 years (Prastawa et al. 2017). The BPPT then allocated the incentive to add a resource on to its ongoing smart grid project and began to install a smart microgrid on its buildings which were located within the Puspiptek-Campus, Serpong, Banten Province. A 10 kWp capacity solar photovoltaic (PV) rooftop system with smart microgrid technology was installed on the top of the one of buildings belonging to the BPPT within the area of Puspiptek Campus. Demand Response, Energy Management System and SCADA were installed in the system. The created design from the previous project was put into consideration to the system. In the end of 2019, the smart meter was added to the system to be connected on grid and hence, the building was able to act as a prosumer (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2017).

The successful implementation of the smart microgrigovernment in Puspiptek -Serpong sent a positive atmosphere to the involved stakeholders. The information about the successfulness of the BPPT in implementing a smart grid demonstration project was circulated not only among the stakeholders within Puspiptek Serpong, but also to stakeholders which were active in Baron Techno Park. After conducting consolidation with its local partner in Baron Techno Park, the BPPT decided to install the technology in Baron Techno Park. The installation was independently financed by the facility. In order to minimize the budget, the smart microgrid was installed on the existing hybrid power plant that already operated since 2012. The project also added a smart meter to the system so that it could sell its excess electricity to the grid.



Note: [house symbol] : Autonomous Permanent Facility;

F6 : Funding(s)/Grant(s) collected independently by research centre;

F3 : Knowledge Sharing as keys to replicate the tes-sites

F5 : Income generation

F4 : Autonomous program(s) issued by research centre;

F2 : R&D project(s) ;

F1 : On-site pilot project for exploring the novel technology;

Goal 1: First on-site testing; Goal 2: Replication of the primary on-site testing

Source: Own Depiction

Figure 7-7 Innovation motor applied to the implementation of a smart microgrid in Baron Techno Park

Smart microgrid in Baron Techno Park : Academics that created its own motor to enable its own entrepreneurial experimentation

According to the theory, the microgrid project in the Baron Techno Park can be categorized as niche creation or at the very early phase of entrepreneurial activities for a particular novel technology due to the goal of the project which was to test the novel technology in a local environment as well as to multiply the testing sites in order to secure the early adoption. It also aimed at being a topic for scholars to discuss and share the potential and knowledge about the innovation. Therefore, the characteristic of the motor that was available to generate the goal was categorized as knowledge motor.

Instead of being based on a top-down program from government as the main engine for its innovation motor, the project showed that the public research institute was capable of issuing its own program in order to move its own innovation motor. At this level, the research institute also contacted its potential funder and organized executors of the program alone. This is quite different to previous studies done by Isoaho et al. (2017) and Mainali (2014) about the early phase of the introduction of radical innovation related to renewable energy in most developing countries, where the availability of projects were very dependent on the availability of top-down programs from the central government in the form of techno-push schemes. In addition, the microgrid project in Baron Techno Park was implemented without any direct supervision program from the government, specifically from neither the energy policy maker nor the research and higher education regulator. This condition was also totally different from the microgrid project in Sumba Island, where the stakeholders of the project were strongly dependent on the exis-tence of the Sumba Iconic Island program issued by the energy regulator. Overall, the projects in Baron Techno Park also depicted the capacity of the public research centre to have independency to extend its horizons towards smart grids as well as to be flexible to establish cooperation projects with other stakeholders.

Related to the sustainability of the project, the smart grid project in Baron Techno Park that was handled by the academics might be more sustainable because it was not stand-alone or had either direct or indirect interrelation with other related relevant projects or programs. Without it, the project would not be able to create a non-stop circle of innovation activities. As the program had a connection with other related projects, it was possible for it to be exposed again through another funding scheme and to be continued, even though it took time. Furthermore, the smart microgrid project in Baron Techno Park was developed under management of a permanent research establishment or was added to an existing permanent facility that enabled it to be long lasting. There were also indications of a strong requirement for a academic or research organization that had already various experiences in smart grid activities in order to carry out a more effective implementation of an on-site demonstration project. This is because the project needed not only expertise, but also network from the experienced organization in order to go on. In this level, the executor of the project, the BPPT, already had experiences in dealing with renewable energy innovations as well as being involved in projects together with national prominent stakeholders, such as the energy policy maker and the incumbent firm for almost two decades (Reber et al. 2016; Badan Riset Inovasi Nasional (BRIN) 2020). Moreover, the capacity of the project to generate income, even though very small, encouraged stakeholders to continue operating those projects. The project in Baron Techno Park installed a smart-meter for PV prosumers that enabled it to get allowance to sell their excess electricity to the grid. Furthermore, the Baron Techno Park was able to be open to the public to be visited and organized various scientific events for students that made the project have more chances to receive revenue to continue.

7.3.2.3 Role of the research and higher education policy maker in developing the smart grid project in Baron Techno Park

Two main activities were done by the research and higher education regulator to directly contribute to the operation of the demonstration project of smart microgrids in the Baron Techno Park, Yogyakarta. Those included participating in learning about the technology and building a network together with the involved stakeholders. However, those activities did not influence the project directly. This is because of two main reasons: 1). The Baron Techno Park was owned by the government of Yogyakarta Pro-vince. According to the Regional Autonomy Act No. 22/ 1999, all central government entities except the ministry of finance, ministry of basic education, and ministry of home affairs could not intervene directly in the operation of the assets that was owned by the local government; 2). Other programs that supported the demonstration project, e.g. smart grid installation and research on designing smart grids done by the BPPT in the Puspiptek-Serpong Campus, were not funded by the research and higher education policy maker, therefore it was difficult for the entity to influence the project and its related activities directly.

In 2012, the research and higher education policy maker tried to build a connection with the government of Yogyakarta Province as well as with the BPPT in order to intervene in the operation of the Baron Techno Park through the assistance of the Indonesian ministry of home affairs. In the common agreement between the research and higher education policy maker and the Indonesian Ministry of Home Affairs No. 3 and No. 36/2012 about the enhancement of regional innovation capacity, it stated that the research and higher education policy maker had rights as well as responsibilities to oversee the implementation of the innovation projects at a provincial level (Indonesian Ministry of Home Affairs (IMHA) and Indonesian Ministry of Research and Higher Education (IMRHE) 2012). Based on this, therefore, the research and higher education policy maker gained access to build cooperation with the local government of Yogyakarta in order to be involved in the development of the Baron Techno Park. However, since the majority of resources and political power are owned by the local government, the research and higher education policy maker tended to play a role as a passive partner in the management of the Baron Techno Park.

Smart grid activities that were undertaken by the BPPT in Serpong and in Yogyakarta Province were among many smart grid programs done by academics that were given attention by the research and higher education policy maker. This was shown by the entitiy through participating in knowledge sharing activities related to those programs between 2009-2011, but only when they were organized by universities and research centres. Thanks to the common agreement between the research and higher education policy maker and the Ministry of Home Affairs, the research and higher education policy maker since 2012 were more actively involved in platforms of information sharing that not only consisted of universities and research centres in Indonesia but also new local stakeholders, e.g., local administrator of the Baron Techno Park.

By dynamically participating as an involved stakeholder in the Baron Techno Park smart grid project, the research and higher education policy maker showed a slight shift in its perspective about the development of the technology. In the beginning, it perceived the smart grid movements done by the BPPT were among many scientific activities carried out by various academic institutions in order to analyze the concept and potential of the technology (Indonesian Ministry of Research and Higher Education (IMRHE) 2015). Subsequently, after the technology was successfully installed and utilized both in Baron Techno Park and in Puspiptek Serpong, the focal entity started to pay attention to the functionality and the possibility of direct utilization of the technology by the society (Indonesian Ministry of Research and Higher Education (IMRHE) 2018).

7.3.2.4 Learning process done by stakeholders through the smart grid project in Baron Techno Park

While providing learning about applicability of the technology for its actors, the project depicted a notable circulation of information or knowledge exchange among actors of the project. In general, the situation of learning processes from the microgrid project in Baron Techno Park showed a lack of participation of a diversified broad range of stakeholders.

Actors from Baron Techno Park, e.g.the local operator and the local government as the owner of the facility, relied on the skills and knowledge of the experts from the BPPT who already conducted the similar projects in the Puspiptek Serpong as the project started. The local operators were also involved in the existing innovation network for smart grids where the experts from the BPPT were working. Subsequently, the local actors exhibited an active learning through direct experiences when implementing the projects, such as learning through dealing with failure or conducting several tests or experiments due to differences in local conditions between Serpong and Yogyakarta, especially in terms of weather conditions and scale of infrastructure (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2016). Publications about the smart grid project in Baron Techno Park as well as in the Puspiptek Serpong were issued by those actors. Those reports and documentations, however, were only limitedly circulated to academics or a limited number of people that had a connection with the BPPT and local government of Yogyakarta (Badan Pengkajian dan Penerapan Teknologi (BPPT) 2016; Gravatar 2020; Prastawa et al. 2017).

To introduce the project to a broader range of stakeholders, the Baron Techno Park opened its facility to the public. The goal was that various potential parties, including smart grid companies, governmental agencies, and potential users were able to see the applicability of the technology in a specific location. This strategy, however, somehow did not really sound the project. The condition potentially related to some circumstances, including: 1) There was geographical distance between Baron Techno Park and those potential parties, especially smart grid experts in Indonesia which operated most of their activities and networks in the surrounding capital city, Jakarta. Those experts bore limited interaction with actors in Baron Techno Park due to the high cost of communication and consolidation due to geographical distance (Hermawati and Rosaira 2017). 2) The characteristics of the technology used in the project were too specific. It could not easily be installed or replicated without a specific configuration based on the specific needs of the consumer (Simatupang et al. 2021). Since the size of market potential of the technology was still quite small, the feedback of the potential consumers for the product was also negligible.

7.4 Discussions: Would the network grow into a system of innovation when it still focused on basic research?

The findings showed in the chapter depicted the existence of collaborative movements dedicated to smart grid technologies within the academic domain that classified themselves into a sort of knowledge-oriented nexus (Network 3) under the informal guidance of the research and higher education policy maker. Subsequently, the nexus demonstrated its potential to be analyzed as a pioneer of a technological innovation system (TIS) based on its achievement in applying network resource management, the existence of interventions from leading actors, and activities to fulfill the functions of a TIS.

Similar to the condition of Network 1 and Network 2, Network 3 also showed a high dependency on a limited number of initiators or resource providers in creating collaborative projects. Nevertheless, the findings show that almost half of the total collective activities within the network encouraged their involved actors to enjoy the asset available during the partnership and generated products together. This condition depicted the potential of the network to deploy a hybrid resource orchestration in order to maximize its performance in implementing functions of a system of innovation. This finding is in line with a study done by Mignoni et al. (2021) and Reypens et al. (2021). In this stage, the elite group of the network might work to stimulate the network due to its reputation, resources, knowledge or political influence. Simultaneously, stakeholders in general were needed to build common consensus for matching their interest to boost their performance at operational level. In other words, the characteristic of the resource organization of Network 3 showed opportunities for its member not only to accumulate and utilize assets together under control of the network, but also to facilitate them to conduct more independent or decentralized activities. Here, the network was seen as a stable platform to facilitate dynamic relationships among members. To conclude, Network 3 had several advantages in terms of network resource management in implementing system of innovation.

Meanwhile, regarding its activities, Network 3 worked predominantly in the field of basic research done within campus. The stakeholders were also quite homogenous. Most of them had the same background because they were from either local R&D centres or local college/graduate schools. The results show that almost 80% of total projects was dedicated to knowledge exploration. Activities of knowledge sharing done by individuals or in class-rooms also significantly contributed to the main activity in the network. On the other hand, the number of on-site demonstration projects that involved end-users were very small within the network. In addition, the involvement of stakeholders at a regime level, such as through being active in proposing recommendations during the policy making process or lobbying with politicians was also very low. Moreover, the network primarily handled smart grid technologies that were still in the form of ideas and concepts that were discussed in classrooms or seminars. The findings also illustrate a lack of direct interrelationship between academics and the smart grid industry (innovators) that made academic insitutions face difficulties in making smart grids into a real business opportunity. To conclude, the network was still in the very early phase to grow into a system of innovation based on its performance at aggregate level.

Subsequently, based on results, the most influential actor of Network 3 was not the research and higher education policy maker but consisted of two groups: insitutions of higher education and the main sponsors (the incumbent firm, the energy policy maker and the ministry of finance). Institutions of higher education worked both as designers and implementers of collaborative movements, whereas the incumbent firm, energy policy maker and the finance ministry provided resources and the rules of the game for the network. The finding was in line with a study done by Del Álvarez-Castañón & Palacios-Bustamante (2021) and Thomas et al. (2021), where the academic domain carried out their movement related to the novel technology by dividing themselves into two groups: the elite sponsors and the majority higher education entities that show their ideas to the elite sponsors. The network may grow to handle more complex functions of a TIS if both the executors and the elite group disclosed their active participation. Nevertheless, in the context of Indonesia, higher academic organizations had a fairly high dependency on these elite actors to carry out their smart grid movements. As long as the elite group could provide positive support, the scholars could conceivably carry on their projects for creating their own alliance for developing smart grid technologies through a series of discussions, consolidations, partnerships and generations of a common long-term plan, and vice versa.

Meanwhile, despite having less capacity in terms of financial, expertise and political power, the research and higher education policy maker was consistent in creating around one tenth of total projects and regularly disclosed its nation-wide research plan. Based on this situation, it was less likely that the research and higher education policy maker could guide smart grid movements within academic domain directly and effectively so that the innovation nexus belonging to the academics can grow to implement more complex systemic functions.

Furthermore, the chapter illustrated the development of Network 3 in implementing the functions of a TIS in a more specific scope through observation towards a particular entrepreneurial experimentation within the academic domain. Smart grid projects in Baron Techno Park were chosen as the sub-case. The project depicted the capability of a single public research organization, the BPPT, in organizing the adoption of the novel technology. According to the theory, the project can be grouped into the early phase of entrepreneurial activities because it still focused on pre-sellable innovation in the local market. The project aimed at testing smart microgrids in the local environment and multiply the site of the test in order to increase the number of early technology adoptions.

Based on its background, Baron Techno Park was the duplication of an on-site test for a smart microgrid in Puspiptek Serpong campus. Both of them were designed and executed by the BPPT. In addition, similar to the adoption of smart-meter PV prosumers in Jakarta, Tangerang and Bekasi that was quite exclusive and above the average of the national situation, the project of smart microgrids in both sites were also quite special. The BPPT was among a small quantity of public research centres in Indonesia that had the capacity to create its own smart grid agenda due to its expertise and close links with the prominent renewable energy players in Indonesia. The entity had been the main partner of the energy policy maker and the incumbent firm in handling various national renewable energy projects since early 2000s (Badan Riset Inovasi Nasional (BRIN) 2020). It also already had its own permanent research facility to study renewable energy that made it easier to install and test any new innovation.

Interesting data collected from the Baron Techno Park was that the project was less dependent on programs from the government. This was not a typical knowledge-oriented entrepreneurial experimentation defined in study done by Isoaho et al. (2017), Gosens & Lu (2013), and Suurs (2009), where government, especially in the context of developing countries, usually just disclose its top-down science and technology schemes to enable stakeholders to implement their movements related to the novel innovation. In the case of Baron Techno Park, the test of the novel technology done by actors was installing an additional component that was compatible with their current infrastructure. In addition, the installation of the novel technology was also capable of generating income from being PV prosumers, even it was still a quite small. It was also able to simultaneously voice its achievement in society, especially between academics, by being open to public. Those reasons conceivably made the project more sustainable or last longer to produce more beneficial results. The disadvantages of the project, however, were that the project did not have the ability to conduct direct lobbying with external potential partners, except the local government of Yogyakarta. The research and higher education policy maker also had a lack of capacity in enhancing the project due to its lower political hierarchy. In addition, since it was located far away from the capital, it faced challenges to sound out its project at a national level in order to invite more investors so that the project could be developed.

7.5 Summary

In general, Network 3 showed that it was still in early stages of its formation of growing into a system of innovation. It still demonstrated its high dependency on a limited number of actors to provide resources. It was also still too focused on basic research. Network 3 depicted a situation where institutions of higher education acted as builders of an innovation ecosystem for smart grid technologies because almost all stakeholders of the network were academics and they implemented their movements inside campus.

8 Comparative analysis and a strategy formulation to enhance the development of three cases of smart grid innovation networks in Indonesia

This chapter demonstrates a comparative analysis between three different smart grid innovation networks in Indonesia. It covers a different level of achievements of each network in having a more open common resource management and performance in handling TIS functions. In addition, the chapter provides a scenario analysis to find the basic elements needed by each network to survive and grow as well as strategies to move forward to the next level of growing into a system of innovation.

8.1 Comparative analysis of circumtances of three cases of smart grid innovation networks in Indonesia

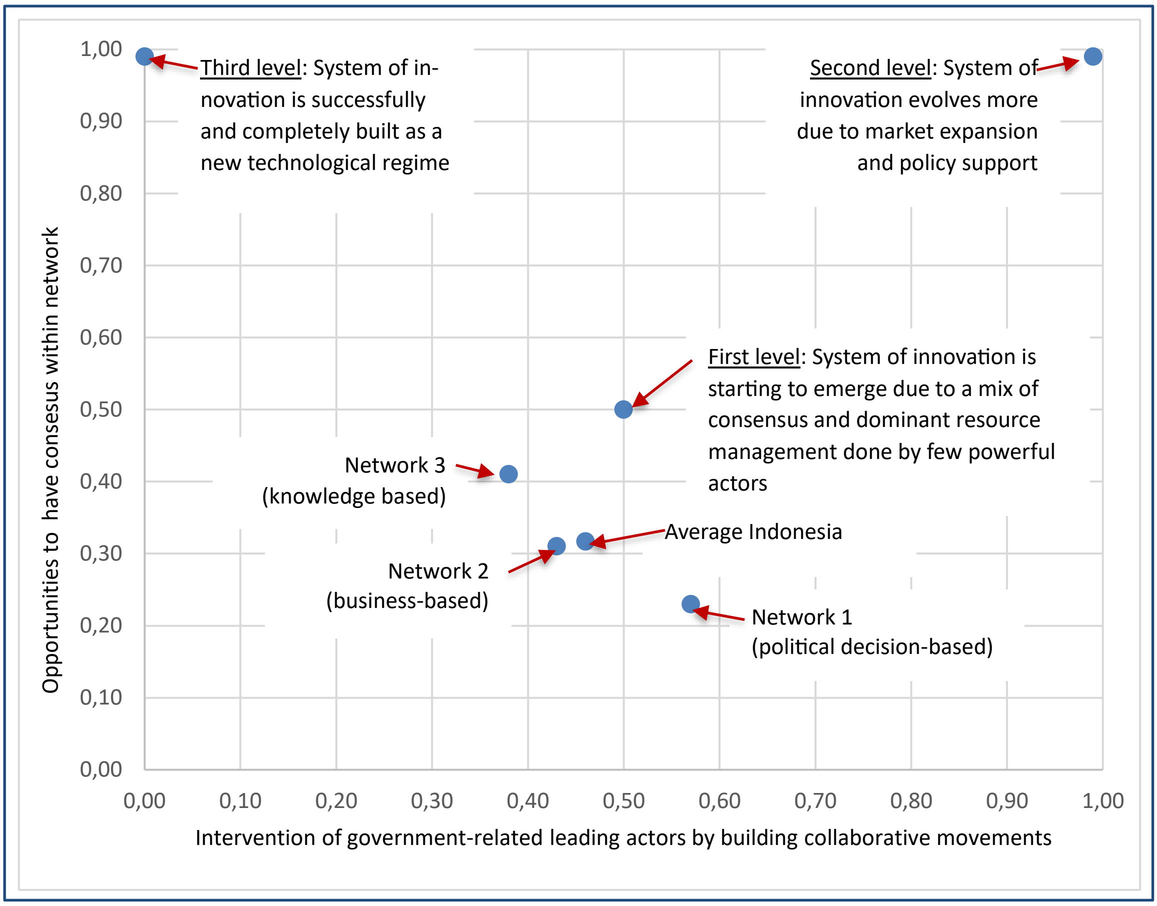
8.1.1 Achievement in the field of resource network management

8.1.1.1 Efforts of leading actors to dominate network vs. freedom of stakeholders to make consensus

Figure 8-1 illustrates different conditions of smart grid innovation networks in Indonesia based on the balance position between efforts of leading actors in intervening in their networks and opportunities for all stakeholders to achieve consensus or to implement an open network resource management. According to the theory, there are three different levels of condition of resource orchestration within an innovation network. Those levels indicate degrees of success of an innovation network to scale up into a system of innovation. The first level occurs as an ecosystem for innovation potentially emerges due to a democracy or a balance of power between consensus built by overall stakeholders and the capacity of leading actors to control the network (Reypens et al. 2021; Fonti et al. 2015; Ahsan and Malik 2015). Or in other words, there is a bargaining position of overall stakeholders towards domination of a limited number of powerful focal actors (Mignoni et al. 2021). This takes place when innovation networks apply a hybrid network resource management. The second level demonstrates a condition where market or utilization of novel technology increases extensively because a significant or maximum amount of incentives from the government is available (Suurs 2009; Smith and Raven 2012). Thus, a system of innovation evolves more. The third level describes a situation where a technological innovation system is successfully built to create a new technological regime because the novel technology is able to be mass produced by depending on freedom and capacity of both firms and end-users (Hekkert et al. 2007; Suurs et al. 2010). In this level, the innovation is able to survive in a fair market competition without any intervention from leading actors, especially in the form of government incentives or subsidies. Figure 8-1 shows that each innovation network reached its own level in managing its network resources.

On average, those three networks depicted that portion of activities of government-related bodies to intervene was somehow still bigger than the opportunities of overall stakeholders to create their own consensus, even though each network showed its own distinctive characteristics. In addition, the value of both variables were at a low or medium level or did not even reach the first level of growing into a system of innovation.

For more details, Network 1 showed a very significant domination of leading actors in determining the development of the network by having a balance position of 0.57:0.23. Meanwhile, network 3 and network 2 had the potential to go to the level of a hybrid network orchestration, or a level where both leading actors and overall stakeholers might be able to be competitive with each other. Network 2 showed a situation where the power of leading actors was only slightly bigger than the capacity of stakeholders in general. It is depicted through its balance position of 0.43:0.31. Network3, on the other hand, demonstrated its own potential to have a hybrid common resource orchestration by having a balance position of 0.41:0.38. If we compare, network 3 had a better condition regarding its common resource orchestration than the two other networks.



Note:
Index of Performance:
0-0.399= low; 0.400-0.549=medium low; 0.550-0.699= medium high; 0.700-0.899=high; 0.900-1= very high

Source: Own Depiction

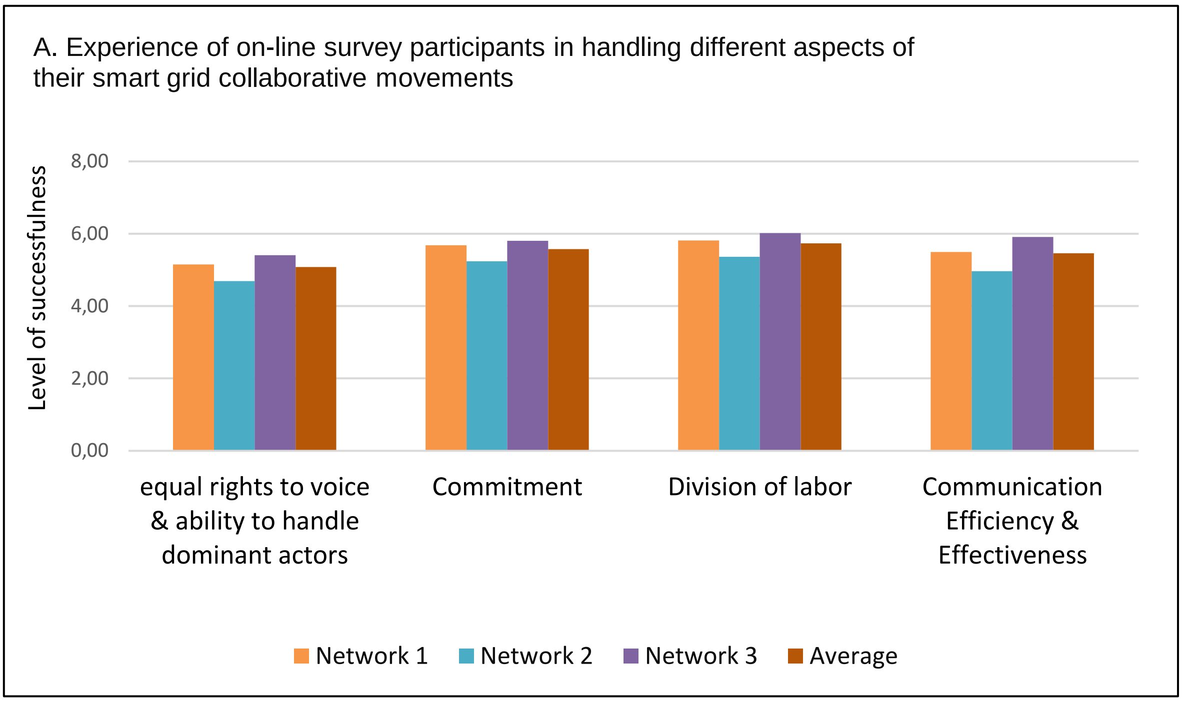
Figure 8-1 Resource network orchestration and intervention of focal actors within three different smart grid innovation networks in Indonesia (2009-2019)

8.1.1.2 The potential relationship between the style of network resource orchestration and the perspective of stakeholders towards the success of their smart grid innovation networks in handling their collaborative projects

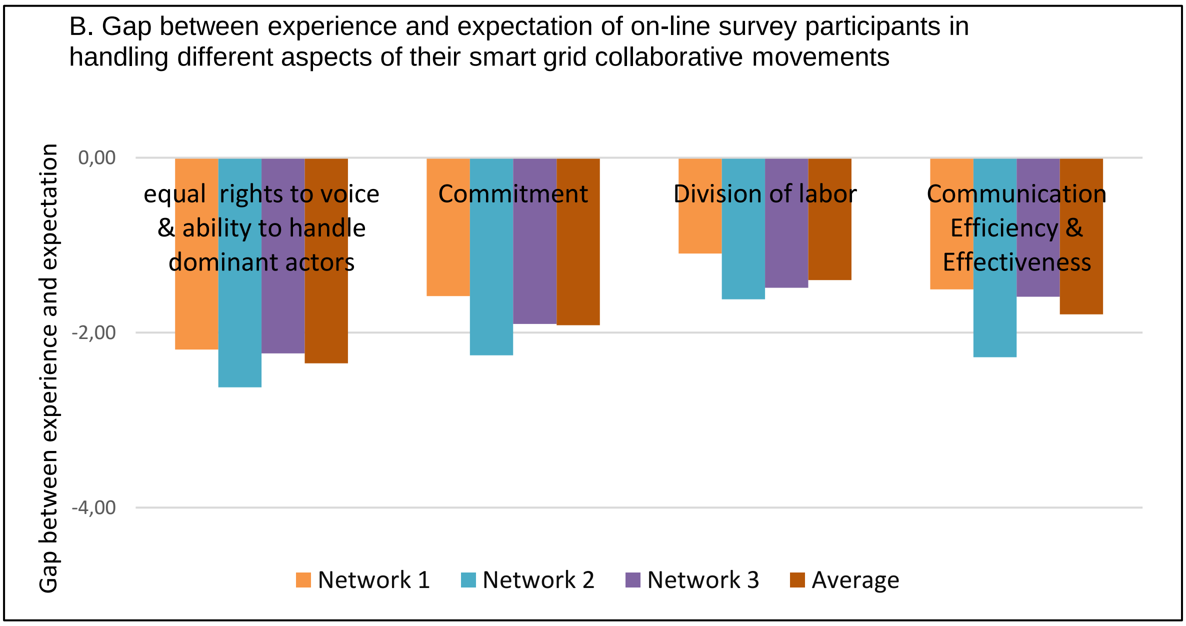
The results of the online survey provided in Figure 8-2 shows the perception and experience of stakeholders of three different innovation networks in handling several aspects related to management of their collaborative projects. It shows that regardless of the type of resource management that those networks had, they still faced a similar pattern of problems regarding common resource management. In addition to that, Figure 8-2 also shows that based on the perspective of stakeholders, their achievement in handling resource management was still below their expectation.

The division of labour was depicted to be easier to handle than other aspects. It reached an average value of success: 5.732. Commitment was at medium to high level with an average value of success of 5.576. Communication efficiency & effectiveness also performed at medium to low (5.549). Power distribution, in addition, that included having the equal rights to voice and ability to handle dominant actors was the most difficult task for stakeholders because it still performed at medium to low (5.084).

Subsequently, the results also demonstrate that in general, stakeholders claimed that they still performed below their level of expectation. The biggest gap between stakeholders' experience and expectation was related to power distribution (average value of gap=-2.351). It is followed by a gap relating to communication and commitment. Meanwhile, the smallest gap was found in the aspect of the division of labor (average value of gap =-1.400).



Note:
level of successfulness (0= not successful at all; 9= very successful)
0-3.99= low; 4-5.49=medium low; 5.50-6.99= medium high; 7.00-8.99=high; 9.00-10.00= very high



Source: Own Depiction

Figure 8-2 Experience and expectation of on-line survey participants from three different smart grid innovation networks in handling different aspects of management of their collaborative projects (2009-2019)

In addition, based on the performance in handling multiple aspects of project management, it is shown that Network 3 performed a better value of satisfaction for stakeholders towards organization of their collaborative movements than the other two networks in general. It had an average performance value of 5.935 (medium-high). The second position was taken by Network 1 with an average performance value of 5.776 (medium-high). Meanwhile, the average performance value of Network 2 reached 5.477 or still at a medium to low. It is also shown that Network 2 peformed less than other two networks in all aspects of resource management. Furthermore, there were some observed circumstances within those three networks :

- Three different smart grid innovation networks had their different goals that also created different levels of expectation and perception of stakeholders towards their movement.
- A higher value of satisfaction in handling organizations of collective movements mostly came from stakeholders that were involved in netwoks that aimed for tackling more specific tasks and covered more short-term projects. This included Network 1 and Network 3.
- Stakeholders from networks that were less populated by innovators but had more experts from academics, including Network 1 and Network 3, showed a greater value of satisfaction in handling different aspects of administration of collaborative movements.
- A perspective of having a better experience in handling organizations of partnership projects was owned by stakeholders that handled projects for less sellable innovations and aimed for exploring the novel technology. This included Network 1 and Network 3.
- Networks that had a larger population of innovators and end-users as well as owned the objective to develop and commercialize novel technology but faced a direct competition with the incumbent firm and its support system had less satisfaction for its stakeholders with regard to their organization of their collaborative movements. This occurred in Network 2.
- Networks that aimed at creating continuous adoption of novel technology but demanded a real fiscal incentive from leading actors experienced a lower level of satisfaction of stakeholders in the organization of their movements. This also took place in Network 2.

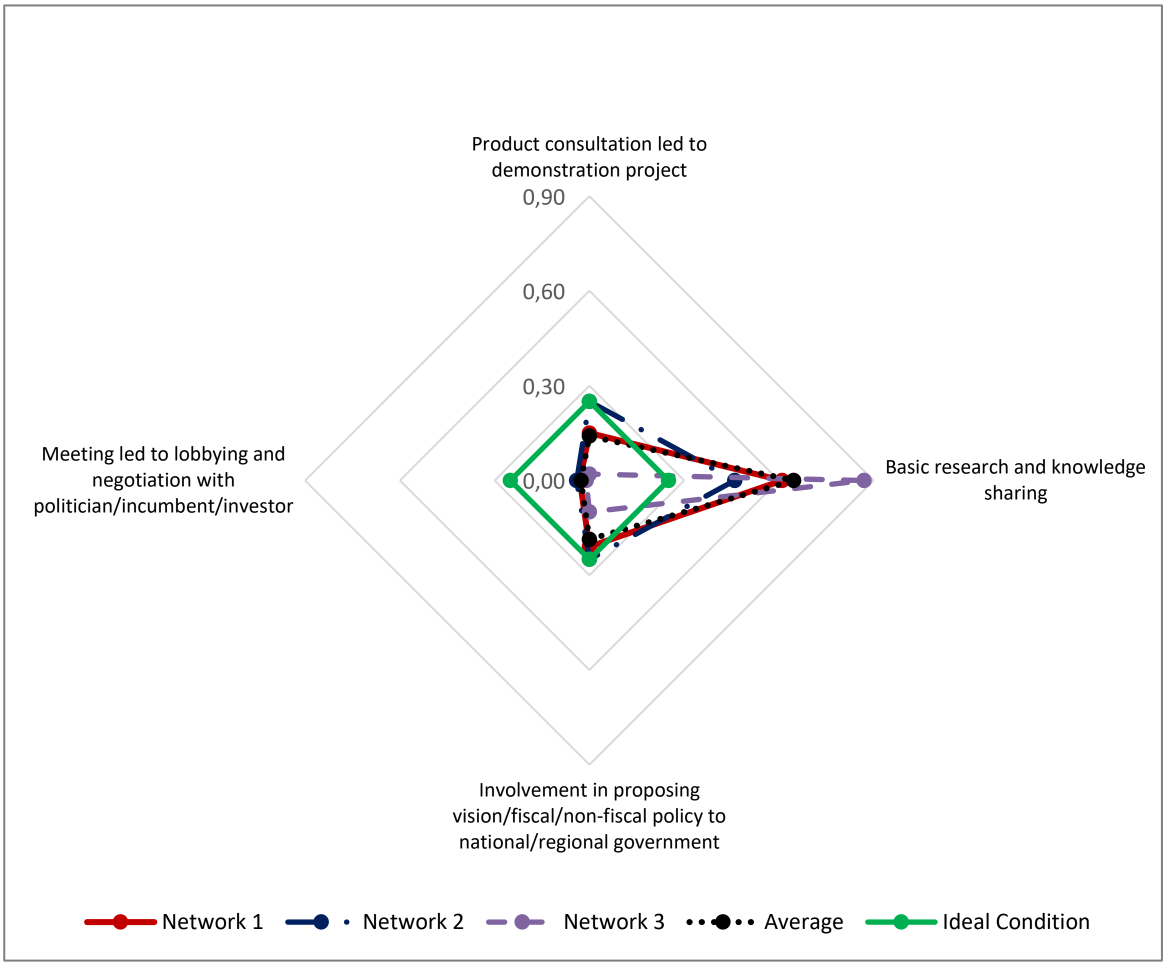
These results show that the style of common resource management did not significantly affect the perspective of stakeholders towards their success in organizing their collaborative movements. All of those three innovation networks showed a quite similar pattern of expectation and experience in handling different aspects of project managements. It was shown that they had a greater competency in the field of division of labor and commitment, but at the same time they face a lower level of success in terms of communication and power distribution among involved stakeholders. Furthermore, based on comparison between the value of success in handling collective movements, in general, it is illustrated that an innovation network that is dedicated to developing and commercializing a sellable novel technology had more difficulties carrying out their activities than an innovation network that was aimed at learning the novel technology. It was reflected through a low level of value of satisfaction of stakeholders from Network 2 regarding management of their collective movements.

8.1.2 Comparison of general performance in implementing functions of a TIS through collective actions

Concentration of collective engagements in performing functions of a TIS

The results derived from an on-line survey shows that all three of the smart grid innovation networks in Indonesia still put their concentration on research and knowledge sharing activities. On average, those networks dedicate around 65% of their resources to carrying out knowledge exploration (See Figure 8-3. Furthermore, only around 2% of total projects from all those three networks that take the form of meetings led to lobbyings and negotiations with prominent politicians or industrialists. Meanwhile, the ideal condition was that those networks should share equally their efforts to implement the four main different functions of TIS, including reseach and knowledge sharing, on-site experimentations, the creation of legitimation to create a political support and recognition from society, and the involvement of stakeholders in the process of policy making.

Nevertheless, if we make a comparison, it can be seen that a network that is under the wings of the incumbent firm (Network 2) worked better than the network supervised by the energy policy maker (Network 1) and the network populated by academics (Network 3) in implementing functions of a TIS. Even though a significant portion of its total collaborative projects still went to managing knowledge about smart grids, Network 2 showed its greater capacity in providing its resources to cover other TIS functions than the other two networks, for example, by having a significant contribution in implementing on-site niche experimentations, providing opportunities for its stakeholders to undertake consolidations leading to negotiations and lobbyings, as well as involving stakeholders in the process of policy formulation. Subsequently, Network 1 was rather more competitive than Network 3 because it tried to conduct pilot projects, to invite stakeholders in to the process of policy making and to do lobbying or negotiation even it was in a very small number of projects. Network 3, on the other hand, sent almost of all its resources to engage in scientific activities. Only a very limited percentage of projects within Network 3 gave opportunities to its stakeholders in policy formulation.



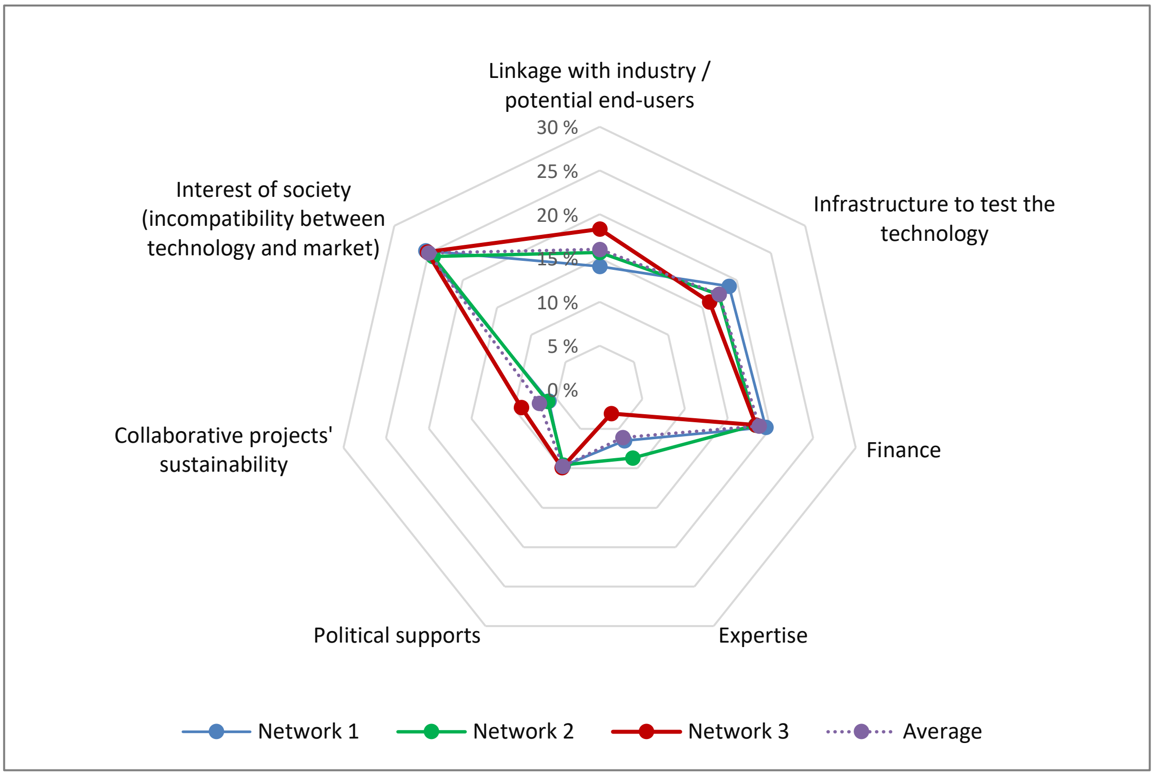
Note:
Index of concentration collective performance:
0-3.99= low; 4-5.49=medium low; 5.50-6.99= medium high; 7.00-8.99=high; 9.00-10.00= very high

Source: Own Depiction

Figure 8-3 Concentration of resources to implement functions of a TIS done by three different smart grid innovation networks in Indonesia (2009-2019)

Concentration of problems

From Figure 8-4 it can be seen that all of the networks had a similarity. They faced two problems, namely the interest of society and political supports. Those claimed that around 10% of their problems during their activities were related to a lack of consistent political supports. In addition, they also reported that social factors were their main problem, including the perception of incompatibility between the novel technology and the current local market condition, smart grid innovations that were still not affordable for most people and a lack of interest from people in accessing actual information about smart grids. It was counted as around one fourth of their problems in general.



Source: Own Depiction

Figure 8-4 Type of challenges faced by different smart grid innovation networks in Indonesia (2009-2019)

Nevertheless, beside social factors and political supports, Figure 8-4 depicts that each network showed its own characteristics of barriers in creating an innovation ecosystem for smart grid technologies in Indonesia. Network 1 that was led by the energy policy maker faced more problems in terms of financial access (19%) and availability of infrastructure to test the technology (19%). Meanwhile, Network 2 that was under the wings of the incumbent firm had more concern on expertise to study and re-develop the novel technology to be more suitable for the local market (6%). At the same time, Network 3 that was guided by the higher and education policy maker had characteristics of problems related to sustainability of collaborative projects (9%) and links with industry and end-users (18%).

Based on the concentration of problems that were faced during the movements in order to create sellable smart grid technologies in Indonesia, Network 3 is seen to be the most problematic. Network 3 had less possibility to create a sort of entrepreurship of smart grid technologies, because it had problems in creating sustainability of its movement and was short in links with smart grid firms or smart grid innovators. Network 1, in parallel, is also seen as less competitive because it lacked potential end-users or destinations to test the potential of the novel technology as well as problems with financial access. Meanwhile, Network 2, even it still had problems due to insufficiency of expertises for re-configuring the novel technology to be suitable in local conditions, it had fewer problems in handling incompatibility of infrastructure to test and adopt the technology, as they were more prepared in term of funding access, had more longevity in conducting collaborative movements, and strong links both with innovators and potential end-users.

8.1.3 Comparison of performance in a more specific scope through achievement in a particular entrepreneurial experimentation

Performance achievement of those three innovation networks in the development as a TIS was also seen in a more specific scope through their capacity in organizing entrepreneurial experimentation of a particular smart grid technology. Based of Table 8-1, it can be seen that each network had its own priorities and achievement in its particular demonstration project. Based on results of the data observation and desktop research of three different entrepreneurial experimentations done by three different innovation networks for the period 2009-2019, it is shown that network under the incumbent firm was rather more successful in performing entrepreneurial experimentation for smart grids than the other two networks (network led by energy policy maker/network 1 and network guided by the research and higher education regulator/network 3). Network 2 showed it had more advantanges than the other two networks, especially related to the aims of the project, types of technology used in the project, diversity of involved actors, and the sustainability of the project.

In terms of implementing the functions of a TIS, Network 2, through the project of rooftop PV prosumers in Jakarta, Tangerang and Bekasi, showed that it could handle more functions simultanously than the other two networks. In addition, there was also a real intervention of government in the form of fiscal policy. The contribution of both early adopters and innovators was also visible through the existence of their lobbying with the policy maker and incumbent firm. In addition, the project showed that it was supported by various activities undertaken by multiple actors outside the location of the project, including R&D, sharing knowledge, funding/investment, and negotiations between actors. Meanwhile Network 1 and te Network 3 showed that their projects were done to cover more simple functions, including prodiving agenda/resources, funding mechanisms, R&D, and knowledge sharing. Network 1 was somehow better than Network 3 due to its availability of platforms for stakeholders to engage in lobbying activities with the energy policy maker.

In addition, the Network 2 chose to use a ready marketable product, whereas Network 1 and Network 3 prefered a product that required reconfiguration so that it can be installed by end-users. Other aspect that made Network 2 more successful was that the aim of the project was to increase the existing market through gaining fiscal incentive from the government. Meanwhile, the project from Network 1 and Network 3 was aiming for testing the technology in the local environment. Moreover, in terms of sustainability, the project within Network 2 may have greater longevity because the technology was already sellable. It could be more developed if there was more supportive fiscal incentives from government or a significant decrease of price of the novel technology.

If we compare between projects from Network 1 and Network 3, it can be seen that the project from Network 3 was more successful in terms of sustainability. The project in Sumba under Network 1 was very dependent on the supply of support from the energy policy maker and the willingness of the utility to act as the early adopter. The project also faced problems related to the lack in capacity of local actors in maintaining the installation as well as in sounding the project out at a national level. On the other hand, the project in the Baron Techno-park under Network 3 was carried out in a permanent facility which already had already infrastructure and was ready to be utilized by the adopter, so that the project may last longer. It was also open to the public in order to sound the project. Nevertheless, the project within Network 1 had greater potential to develop because the capacity of stakeholders to access communication with the policy makers through lobbying, and the diversity of involved stakehol-ders. In addition, it was also very possible for the potential adopter, in this case the incumbent firm, due to its economic capacity and support from the government, to multiply the site of the project that must not be in rural areas, but also in different regions in Indonesia where the compatible infrastructure already existed.

Table 8-1 Comparison of performance of three different smart grid innovation networks in handling a specific entrepreneurial experimentation (2009-2019)

Criteria	**Network 1**	**Network 2**	**Network 3**
Name of project experimentation	Case 1 (Based on Sumba smart microgrid project)	Case 2 (Based on smart meter for rooftop PV prosumers in Jakarta, Tangeran and Bekasi city)	Case 3 (Based on smart microgrid project in Baron Techno Park)
Type of introduced technology	Smart microgrid	Smart meter for rooftop PV prosumers	Smart microgrid
Specification of technology	Sellable but needs to be customized to meet requirement of users	Needs uncomplicated installation and was sellable	Sellable but needs to be customized to meet requirement of users
Type of end-user	Distributed hybrid power plant owner / utility	households with rooftop PV installations	Permanent research facility or techno-park with hybrid power plants
Level of entrepreneurship activity/type of innovation motor	1. Level (niche technology)/knowledge motor	2.Level /systemic business motor	1.Level (niche technology)/knowledge motor
Aims of motors	To test functionality of technology in a certain local condition	To improve and expand initial market	• To explore, test and improve functionality of technology • To replicate experimentation projects in different places • To maintain sustainability of early adoption
Type of TIS function that created innovation motors	Lobbying with government	End-users/early adopters and innovators	Ability of academics in creating program and collecting funding to implement program
Activities to start the motor	Programs issued by government but as a result of lobbying done by NGOs and universities	Adoption of technology by limited number of end-users	Programs of academics to provide a compatible infrastructure to execute the project
Main actor	Public research centre and the incumbent firm (as adopter)	Early adopters (households) and innovators	Public research center (as installer)
Overall Actors	Incumbent firm, policy maker, and public research centre, local government	Heterogenous actors (early adopters, innovators, energy consultants,	Most activities circulated between academics

Criteria	Network 1	Network 2	Network 3
		universities, incumbent firm, policy makers)	
TIS functions performed in the motor	Lobbying, program from government to provide project's legitimacy, funding, R&D, and knowledge sharing	• Main motor: limited adoption of novel technology, lobbying with policy maker, fiscal policy • Supporting motor: sharing information, R&D, and lobbying (to gain access to funding / investment), investment/funding, experiment projects	Program of early adopter (management of Technopark) to provide infrastructure of the novel technology, seeking for investor/funder, R&D, knowledge sharing, experimentation of the novel technology
Sustainability of the project	It could last as long as there was availability of the program from government to provide resources.	• It had longevity because technology was still marketable. • It would develop into a bigger movement as long as either the cost of the technology decreased or more supportive fiscal incentives were available. • Possibilites to create a new business model (for example: prosumers aggregator or microgrid-prosumers)	• It had greater longevity because the technology was installed in a permanent facility and used daily. • It was open to the public, especially students. • It generated income from public visit and installing smart-meter rooftop PV prosumers. • The model of the project can be adopted in other places, for example campuses, government offices and hospitals.
Situation on learning process	• Technology was not from locals, it takes time to explore • High dependency on external installer to operate the technology • High dependency on focal actor (utility) and government to sound	• learning through using the technology and dealing with failures • availability of various non-government platforms to share experience in using the technology and to collectivelly access communication with policy maker	• Technology was imported from abroad, it takes time to explore • Circulation information was mostly done among academics that have a contact with the project's executor • Geographical distance that conceivably

Criteria	Network 1	Network 2	Network 3
	the project out at national level		hindered sharing information
Problems	Barriers to sustainability of the demonstration project due to: • Decreasing interest of government to provide program or to actively conduct funding facilitation • Lack of capacity of local operators in maintaining the installation	• Inconsistency of government in providing incentives • Less competitive environment between innovators and incumbent firm	Limited access to finance in order to extend and sound the project out; and lack of connection with industry and private potential end-users.

Source: Own Depiction

8.2 Discussions

8.2.1 Similarity of performance between three smart grid innovation networks in Indonesia

- High concentration on knowledge exploration

The results show that all three smart grid innovation networks in Indonesia did not yet successfully perform more complex functions of a TIS. This is contradictive with the need of a TIS that should have stakeholders that are able to handle different systemic functions simultaneously. This is because one function can influence other functions in the process of creating either a virtuous cycle or even a vicious cycle of a new technology field (Kao et al. 2019; Bergek et al. 2008b; Hekkert et al. 2007).

In contrast, those innovation networks concentrated the majority of resources collectively to undertake knowledge exploration related to the novel technology. The result was in line with studies done by Esmailzadeh et al. (2020), Mohammadi et al. (2013), Byrne et al. (2012), and Elias und Victor (2005), where most of the developing countries still focus on its research and knowledge sharing activities in handling novel innovations that are from abroad and totally new for local situations, including renewable energy technologies. Therefore, knowledge exploration about how to test and reconfigure the innovation to be suitable with the local environment is still the priority.

- Problems related to social barriers and political supports

All three networks still faced similar problems, especially related to social barriers and political support. Social barriers within those networks included the perspective of the majority of society that smart grid technologies were not yet the suitable products for the current market due to a shortness of compatible infrastructure as well as the cost of the technology that was still affordable only for a limited number of communities. Meanwhile, problems related to political support was about the inconsistency of policy makers in providing incentives and an absence of less beurocratic procedures for potential adopters to install the novel technology.

Those findings are also in parallel with studies done by Huang et al. (2020c), Hussain et al. (2017), Vladimirov & Galev (2016), and Kebede et al. (2015). They assert that a negative correlation between the utilization of conventional energy and thesuccessful introduction of renewable energy technologies may remain as long as there is still a lack of engagement from society to participate. Subsequently, in the context of developing countries, the process of diffusion of renewable energy technologies is conceivably hindered by difficulties in accessing information about the novel innovation (Seetharaman et al. 2019). Furthermore, even after the new technology is successfully installed, so-ciety is possibly lacking the culture to maintain the operation of the installed innovation because of the high levels of complexity of the technology that is too difficult for the local society to utilize privately and simulta-neously (Darmani et al. 2014; Isoaho et al. 2017; Arocena and Sutz 2002). In addition, a large part of the population that still struggle to get acces to basic energy services decreases the eagerness of society to inform themselves about the innovation as it is not their current priority (Hillberg et al. 2019).

Meanwhile, an insufficient interest of government in generating programs for green technologies worsened the level of societal engagement. Furthermore, the renewable energy technologies may remain more expensive than the the one that is based on fossil fuels also make people have little interest in sustainable energy innovations (Ahuja et al. 2009; Kayal 2008). In this context, the political will and coordination of policy makers to overcome barriers for potential technologies that may be applicable in poor countries through providing incentives are necessary (Tigabu et al. 2015b; Arent 2017; Gliedt et al. 2018). It is important that in the process of introducing a novel green innovation, policy makers are required to facilitate learning across multiple stakeholders through platforms for knowledge exploration and re-configuration of novel innovations in order to ease the process of adoption (Anadon et al. 2016).

8.2.2 Business-based network performed better than political decision-based network and knowledge-oriented network in building a system of innovation

The results in Table 8-2 illustrate that network under the coordination of the incumbent firm (Network 2) worked better in handling different functions of a TIS. This is line with the study done by Pushpananthan (2022) and Mao et al. (2020). They assert that the business netwok usually works more efficiently in implementing systemic functions of innovation mainly due to the basic goal of the network itself which is to conduct business related to the novel technology. In addition, Network 2 aimed at commercializing innovation through the accumulation of resources that then can be exploited and re-created over a long term period. In order to do that, the network chose to handle a novel technology that was more ready to be commercialized, especially to private households. In the process, the network started to handle multiple taks simultaneously, because it knew that those taks were just like components of a machine that worked hand in hand to create its optimal output. This was different with networks that basically aimed for knowledge exploration that were undertaken by universities which included Network 3, or networks that aimed for something specific but based on a short-term agenda from government, such as networks for aiming diffusion of a certain novel technology in a specific geographichal area which included Network 1. In case of Network 2, the capacity of the network in performing different duties of a TIS due to the composition of its stakeholders that were more heterogenous than the other two networks (Network 1 and Network 3). The stakeholders consisted not only of academics, but also a significant number of innovators, private energy consultants who were eager to promote the novel technology, policy makers and end-users. In addition, the innovators were able to initiate most of the projects to attain various objectives, such as on-site pilot testings, lobbyings, and research projects within the network to create cooperation with the incumbent firm.

Table 8-2 Summary of the achievements of different smart grid innovation networks in Indonesia (2009-2019)

Network	**Performance at aggregate level** Based on type of TIS functions that had been performed *(done by more than 3% of total respondents of on-line survey)*	**Performance at a specific niche experimentation** Based on type of TIS functions that had been performed	**Strengths**	**Weaknesses**
Case 1	++++ (Total 4) (policy formulation, knowledge exploration, lobby with politicians & industrialists, and on-site experimentation)	++++++ (Total 6) (R&D, knowledge sharing, investment, program formulation, on-site test, and lobby with the government)	• Diversity of actors • Capacity to access communication with policy maker and the incumbent firm	• very dependent on support from the government and cooperation of the incumbent firm (as an example of early adopter) • still focuses on knowledge exploration
Case 2	++++ (Total 4) (policy formulation, knowledge exploration, lobby with politicians & industrialists, and on-site experimentation)	+++++++ (Total 7) Main motor: fiscal incentive provision, adoption by high-income households, lobby with the government and incumbent firm Supporting motor: R&D, knowledge sharing, investment, program/vision formulation, on-site test	• Diversity of actors • Prefer to handle marketable product • Increasing numbers of end-users • Possibility to create a new business model	• Early adopters were still only high-income households, campuses and public facilities • Inconsistent and unsupportive fiscal incentives

Case 3	+++ (Total 3) (policy formulation, knowledge exploration, and on-site experimentation)	++++++ (Total 6) (R&D, knowledge sharing, investment, program formulation, on-site test, and fiscal incentive provision)	• Specialist for basic research	• Mostly populated by academics • Lacked contact with end-users and industry • Lacked continuous collaborative projects • High dependency on government to provide resources • Lacked political power

Note:

+: number of functions of TIS that had been performed

Source: Own Depiction

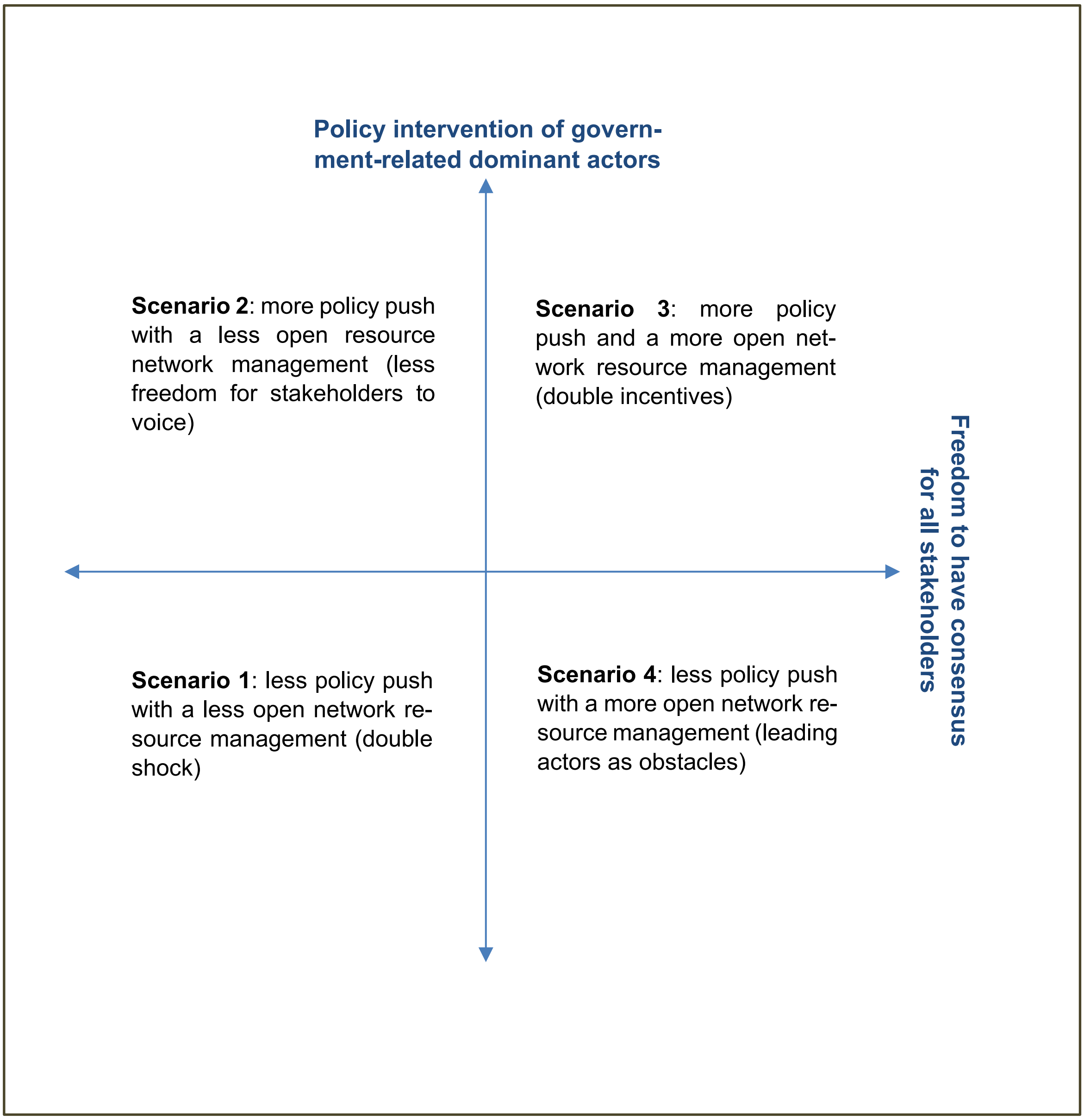
8.3 Scenario analysis based on style in managing network resources to optimize the operation of a TIS

Scenario analysis undertaken in this study utilized an assumption that the development of the novel technology is static. The second assumption is that the minimum level innovation networks can grow optimally into a system of innovation, when both democratic network orchestration and incentives from leading actors are maximized.

The first level of achievement of a network in growing up into a system of innovation is when a hybrid resource management takes place. It is depicted by a value of average of opportunities to have open network resource management and intervention of leading actors which is 0.50. The next level is when both fiscal and non fiscal policy are maximized together with massive utilization and production of novel technology. The condition is described as the value of average opportunities to have open network management and the intervention of leading actors in optimizing the operation of TIS functions is at maximum value which is equal to one.

Subsequently, this study presented two different data calculations: <u>first</u>, when the development of innovation networks depended only on a single government-related leading actor; and <u>second</u>, when the development of innovation depended on at least two government-related leading actors. In addition, the data to illustrate the state of the art of the scenario analysis was based on results of an on-line survey undertaken in this study that was about access to collective resources within collaborative projects and the intervention of leading actors through the initiation of partnership projects. This data was presented in Chapter 5 for Network 1, Chapter 6 for Network 2, and Chapter 7 for Network 3. They depicted that the more support undertaken through actions of a greater number of leading actors, the more possibilities of networks to develop, and vice versa. For the first calculation, Network 1 had the highest value of average of opportunities between having an open network management and intervention of leading actors (score =0.26). It was followed by Network 3 (score=0.25) and then Network 2 (score=0.22). Meanwhile for the second calculation, Network 1 and Network 3 had the same value of average of opportunities between having an open network management and intervention of leading actors (score =0.40), whereas Network 2 had a score of 0.37.

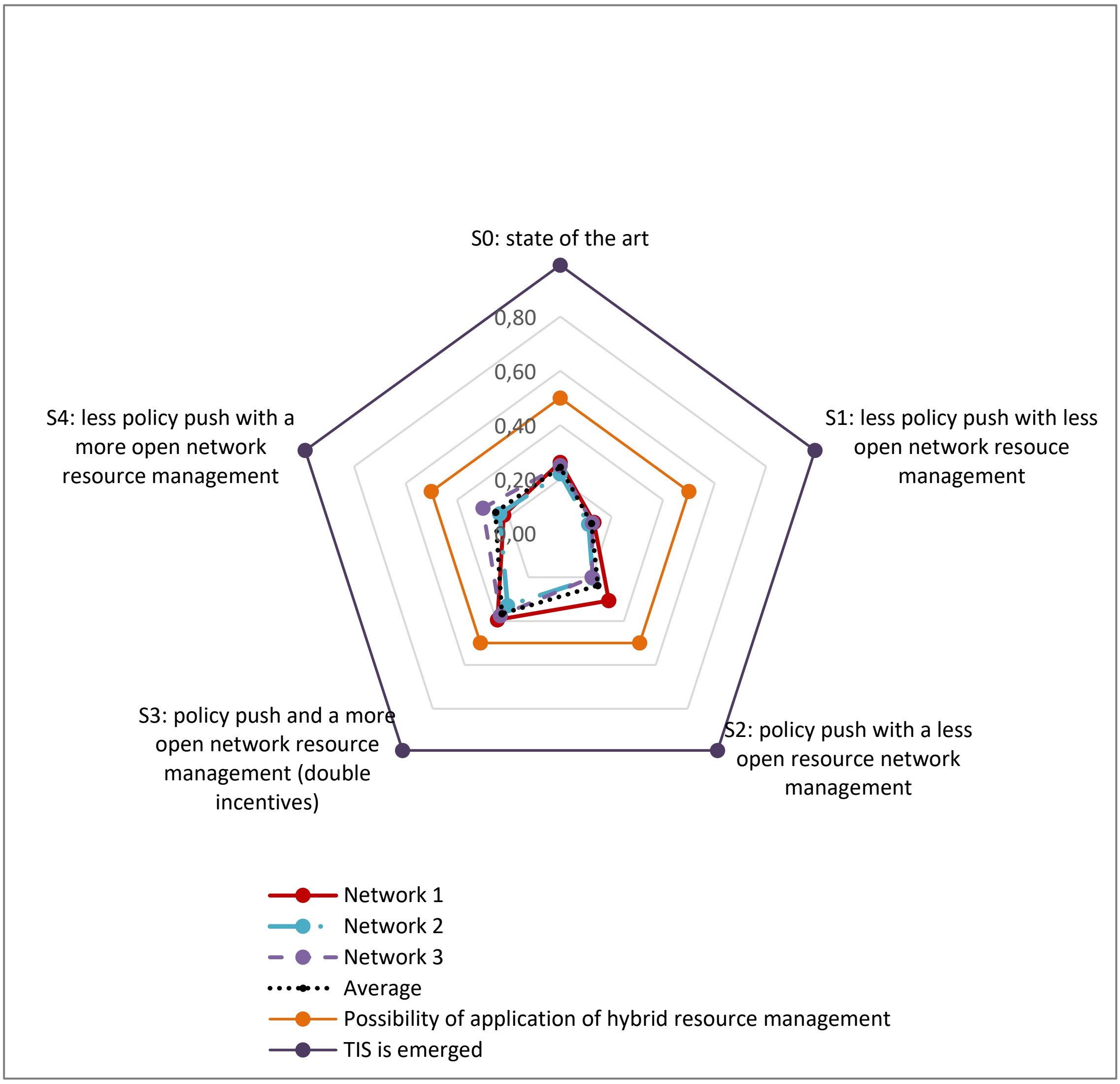
Furthermore, Figure 8-5 illustrates four scenarios of the performance of innovation networks. Overall, it describes that the development of a novel technology field in developing countries, specifically in Indonesia, is about competition between the intervention of government-related dominant actors and opportunities of overall involved actors in having consensus or democracy to use collected resources to maximize the benefit in developing, utilizing, and commercializing novel technology. The scenario is done by applying the assumption that the development of the novel technology is static (Bittencourt et al. 2021; Musiolik et al. 2012; Ahsan and Malik 2015). The first scenario is about a situation where there are fewer policy supports as well as fewer opportunities for stakeholders to build consensus in handling the arrival of the novel technology. The second scenario happens as there is a more support given by leading government-related actors but at the same time there are fewer opportunities for stakeholders to voice their opinions. The third scenario takes place when overall stakeholders have a greater bargaining position to face the leading actors which is also helped by more incentive given by leading actors, so that all stakeholders are able to develop the novel technology together. In addition, the fourth scenario is about the condition where most of the novel technology was handled due to the freedom of overall stakeholders to accumulate common resources together and create consensus among themselves, even though at the same time there is insufficient support from government related bodies.



Source: developed by author by compiling concepts from (Ahsan and Malik 2015; Bittencourt et al. 2021; Musiolik et al. 2012).

Figure 8-5 Model for scenario analysis used in this study

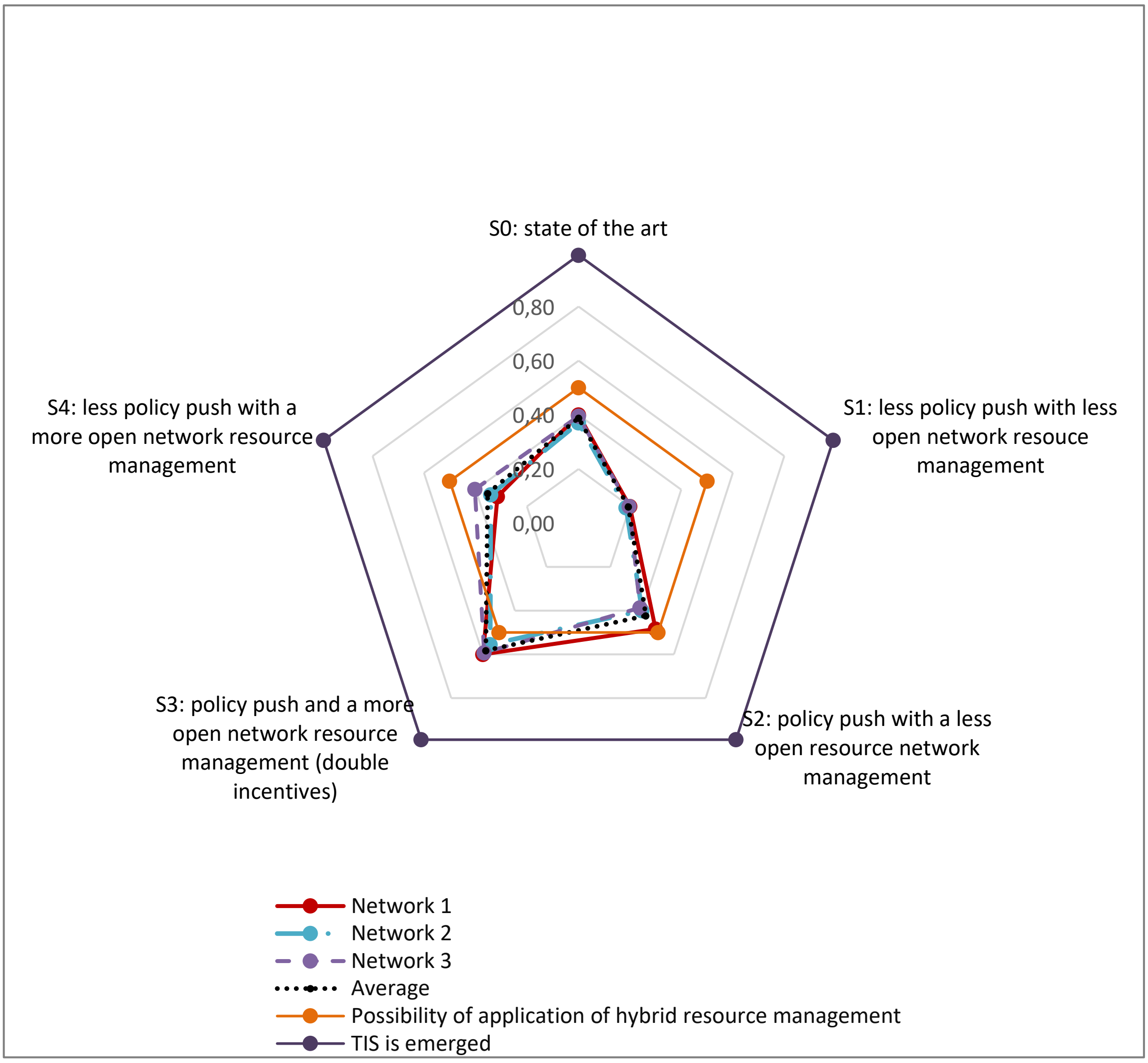
The results provided in Figure 8-6 and Figure 8-7 show that the value of average opportunities to have open network management and the intervention of leading actors for all scenarios from the first calculation is lower than the second calculation. It means that those three networks were able to develop more when there was a greater number of involved government-related leading actors. Figure 8-7 demonstrates that by having more encouragement from more than one leading actor, it was possible for all the networks to reach a level where there was a competitive environment between overall stakeholders and dominant actors. More leading actors conceivably lead to more possibilities to have support and initiation to build collaborative movements. Multiple leading actors may also hinder a single entity to solely control the network.



Note:
Index of Performance:
0-0.399= low; 0.400-0.549=medium low; 0.550-0.699= medium high; 0.700-0.899=high; 0.900-1= very high

Source: Own Depiction

Figure 8-6 Result of scenario analysis when operation of TIS faced intervention from a single government-related leading actor (first calculation)



Note:
Index of Performance:
0-0.399= low; 0.400-0.549=medium low; 0.550-0.699= medium high; 0.700-0.899=high; 0.900-1= very high

Source: Own Depiction

Figure 8-7 Result of scenario analysis when operation of TIS faced intervention from several government-related leading actors (second calculation)

Based on Figure 8-6 and Figure 8-7, it is shown that Network 1 tended to grow when there was support from leading actors. Consensus was less important to the network. Furthermore, Network 1 could grow to a maximum when there was both support from leading actors as well as consensus among its stakeholders. This is consistent with previous analysis provided in Chapter 5, where the network had greater dependency on top-down agendas from government. In addition, the result demonstrates that besides support from the government, communication among overall stakeholders about the suitability of the technology in the local market and the possibilities to solve the issue and enhance the sustainability of the network was also essential.

Meanwhile, Network 2 was a network that could grow better when there was more opportunities for all stakeholders to have a type of democracy or freedom in handling the novel technology, even though there was less support from leading actors (See Figure 8-6 and Figure 8-7). Furthermore, it could develop even more when both support from leading actors and consensus were available. This is also consistent with results provided in Chapter 6. It is shown that a less fair competition between innovators and the incumbent firm was still problematic for overall stakeholders to introduce the novel technology. The situation potentially worsened as the government tended to support the incumbent firm in controlling the early adoption of the novel innovation. Less ''democracy'' was also shown by difficulties faced by early potential adopters to get a license from the government to install the novel technology.

Network 3, on the other hand, liked to prioritize the consensus among its stakeholders. It could grow significantly as long as there was more opportunities to voice an opinion among all stakeholders (See Figure 8-6 and Figure 8-7). It could survive in a situation where there was limited support from leading actors, as long as there was freedom for stakeholders to have consensus. According to analysis provided in Chapter 7, the consensus was mainly about freedom for universities to define their research topics related to smart grid technologies.

Furthermore, Network 1 and Network 3 were networks that had greater ability to survive in a situation where there were fewer opportunities to utilize and accumulate common resources and less support from leading actors than Network 2. This is consistent with the aim of Network 1 and Network 3 that still focused on exploring the novel technology. Especially in Network 3, where commercialization was not its main objective. Even when the novel technology was not able to be developed in the local environment, the majority of actors in Network 3 which were academics, still had the chance to discuss the technology in classes or seminars. The situation was different with Network 2 that aimed more for business. When there was neither political support nor opportunities to develop and utilize the technology, the network might collap.

8.4 Strategies to move forward

Based on the results of the achievements in implementing functions of a TIS and scenario analysis, it can be seen that each innovation network had its own goal. Network 1 aimed for knowledge exploration about smart grids through implementing top-down government programs related to rural electrification. Meanwhile, Network 2 worked to be able to sell smart grid technologies in the local market. At the same time, Network 3 focused on basic research and knowledge sharing about smart grids on campuses. Those different goals then conceivably defined the speed as well as the possibility of those networks to be able to grow into a TIS. Based on studies done by Musiolik (2012), Suurs et al. (2010), and Suurs (2009), a group of collective movements might be able to create a system of innovation for a new technology field if those movements aimed for commercialization and the changing of current technological regimes. Based on this, it can be seen that only Network 2 had more chances to grow faster into a system of innovation. Subsequently, Table 8-3 summerizes the condition of each different network and possible strategies to move to the next level of the process in developing into a system of innovation for smart grids. It can be seen that Network 2 had a greater potential to emerge sooner than other two networks. This was because the activities of Network 2 were aimed at making the novel technology marketable in local society. Furthermore, based on the results of the scenario analysis, each network might need its basic elements to survive or to grow in order to go to the next level of growing into a system of innovation.

In Network 1, it is found that it prioritized top-down agendas from government in order to survive. However, at the same time, the network had problems related to a high level of dependency on programs from the upper level of government organizations to continue its movements. Problems related to insufficient coordination with actors at grass roots level to talk about the incompatibility between the novel technology and readiness of the local market still remained. To solve this, the government may have to engage more consolidations with actors at a niche-level in order to be able to apply a more bottom-up approach for its programs. The approach, according to Bush et al. (2017) and Chung (2013), might help the government, especially in developing countries, to be more efficient and effective in allocating its limited resources. Furthermore, the maneuver may also enable the project's executors or local society to decide the type of technology that may be suitable for the local condition (Ristanti and Yan 2015). When this strategy was applied, the network conceivably could have gone from being only a platform to explore and share knowledge to a nexus that was aimed at the development of a niche market for the novel technology.

Table 8-3 Possible strategies for three different smart grid innovation networks in Indonesia to move to the next level of growing into a TIS

Network	**Main objective**	**Achievement in implementing TIS functions**	**Current level of growth into a TIS**	**Prioritized element to develop**	**Challenges to grow**	**Ways to move forward**	**Next possible level** (the most ideal level= 4.level or mature level, where network functions to create a new technological regime or a new industry without incentive or protection from government)
Case 1	To implement top-down agendas from government related to rural electrification based on renewable energy	• Dominated by projects aimed at knowledge exploration about the novel technology • Had a small distribution of activities for niche experimentations and negotiations with politicians & incumbent firm	1. Level (network as a platform for exploring and sharing knowledge)	Supports in form of programs with funding opportunities from government-related leading actors	• A high dependency on supports from government-related leading actors in the form of short-term a top-down agendas • Lacked communication between stakeholders about incompatibility between markets and the novel technology	• Possibility to increase coordination with actors at a grassroots level in order to develop a more bottom-up approach which may enable greater participation of stakeholders in order to optimize the limited capacity of government in creating and delivering resources through its program (Chung 2013; Bush et al. 2017). • Possibility to test the novel technology in different areas and change the type of technology that has greater potential to be commercialized (Ristanti and Yan 2015).	2.Level (network as platform to enhance creation of niche market)

Case 2	To commer-cialize smart grids	• Resources were distri-buted not only for knowledge ex-ploration, but also for com-mercialization of the novel technology. • Had several plaftforms to en-gage communi-cations with in-cumbent firm and govern-ment.	2. Level (network as platform to enhance creation of niche market)	More opportuni-ties for stake-holders to build a common con-sensus to accu-mulate common resource without too much domi-nation of leading actors, e.g., in-cumbent firm and government	• Relatively unfair competition be-tween stakehol-ders, specifically in-novators & end-us-ers, and incumbent firm • Inconsistent incen-tives from govern-ment	• Possibility for the incumbent firm to create a joint-busi-ness unit with smart grid in-novators in a specific area or specific type of technology (Ivarsson 2018) • A fair competition between overall stakeholders, specifi-cally innovators and early adopters, and leading actors, especially the incumbent firm and its supports from go-vernment (Cozzolino et al. 2021; Ranganathan et al. 2018)	3.Level (network as a plaftorm to enhance production of the novel technology at a large scale with support from government)
Case 3	To study smart grids	Most of the projects dedicated to knowledge explora-tion.	1. Level (network as a platform for explo-ring and sharing knowledge)	Freedom for stakeholders to decide their re-search topic	• A high dependency on funding supports from government-re-lated leading actors but had greater free-dom to choose the topic of study • A limited capacity to do activities beyond basic research and sharing knowledge	• Maintains freedom to decide the topic of research as well as increase the funding pos-sibilities by conducting con-solidation partnerships be-tween academic entities(Cai et al. 2020a; Leon and Mar-tínez 2016) • Possibility to join or to facili-tate seminars or discussion forums that involve end-users and industry to extend the horizon of stakeholders as	2. Level (network as platform to enhance creation of niche market)

					• Lacked links with innovators and end-users • Greater concentration on teaching than research activities	well as to have opportunities to create partnership programs with industry (Drucker and Goldstein 2007; Taxt et al. 2022) • Possibility to invite industry or end-users in classes (Heaton et al. 2019; Rissola et al. 2017; Spiegel et al. 2016)	

Source: Own Depiction

Network 2, on the other hand, mainly needed a more open network resource management that could provide greater opportunities for its stakeholders to accumulate and exploit resources in order to develop and commercialize the novel technology, especially in the long run. The problem was that it still faced an unfair situation between stakeholders, mainly early adopters and innovators, and the incumbent firm (state-owned utility). This is due to the tendency of government in supporting the current technological regime. Besides a fair business environment that should be developed between innovators and the incumbent firm, Cozzolino et al. (2021), Ivarsson (2018), and Ranganathan et al. (2018), through their research, propose that one of both parties should initiate a joint-business unit in order to handle the novel technology together. By adopting this method, the incumbent firm has a greater chance to find out the ‘’black box’’ of the technology and may be able to re-develop it alone. Meanwhile, through the joint-business arrangement, the innovators gain greater power through being able to connect with structure of the local market and to be recognized by local society as partners of the incumbent firm (Feng 2016). Based on this tactic, Network 2 may have been able to expand from being a nexus for creating a niche market into a platform of a broad range of stakeholders that was able to enable the novel technology to be mass-produced.

Meanwhile, freedom for stakeholders to define their activities was the greatest priority for Network 3 to sustain itself. Nevertheless, in an actual situation, it still faced a high dependency on leading actors to finance its activities. Other problems were also related to a focus of local universities to handle more basic research and teaching rather than to develop experimentation that involved industry and end-users. Based on this situation, Cai et al. (2020b) and Leon & Martínez (2016) propose that universities have the possibility to decrease their dependency on government as well as maintaining their freedom in exploring knowledge through consolidations and partnership initiatives among themselves. In addition, Drucker & Goldstein (2007) and Taxt et al. (2022) suggest that universities should be more visible in forums that involve new entrant firms or innovators and end-users. By doing this, they may have greater opportunities to expand their knowledge as well as to engage in more commercial-oriented movements. Meanwhile, Heaton et al. (2019), Rissola et al. (2017), and Spiegel et al. (2016) assert that it might be not bad if universities tried to invite more experts from industry as well as representative of early adopters of the novel technology to share their experience and vision in classes or seminars in campuses and schools, so that students develop eagerness to transform their idea into real business opportunities.Through these strategies, it was possible for Network 3 to move from being a research and knowledge sharing nexus to a network that was able to develop a niche market for the novel technology.

8.5 Summary

The results provided in this chapter illustrate the different levels of goal, focus, capacity and opportunity to move forward three different types of smart grid innovation networks in Indonesia. Nevertheless, those networks experienced a similarity in the form of a high concentration of activities for knowledge exploration related to the novel technology. It depicted a fairly limited capacity of stakeholders in creating links with a broader range of players that were able to generate a virtuous cycle or ''nursery'' for the novel technology. It also showed that the novel technology, in general, was not ready to be directly commercialized without reconfiguration or multiple tests done by early adopters. In addition, they also simultaneously reported a lack of interest in society towards the innovation, especially due to its costs, needed supporting infrastructure, and limited access to information about the innovation. Furthermore, the lack of political support was also seen as a common challenge for those networks.

In addition, the results also provide information that the network aimed for business (Network 2) worked better to implement functions of a TIS than the network that had a high dependency on support from governments or was too focused on knowledge exploration (Network 1 and Network 3). Network 2 showed greater progress in handling various activities in order to commercialize the novel technology by providing more opportunities for its stakeholders to collect and utilize the common resource to handle multiple functions of a TIS simultaneously, including research, knowledge sharing, lobbying with incumbent firm and policy makers, and implementation of demonstration projects. Those activities enabled the network to exploit and re-develop ideas and assets sustainably so that the business of the novel technology grew. Meanwhile Network 1 and Network 3 focused more on short-term projects that were dedicated in handling specific tasks without concern on building a long-term common goal.

Subsequently, based on their achievement and results of the scenario analysis, it is shown that each network had its own current position to move forward. In addition, each network also had its own specific elements or keys in order to grow. In this context, Network 2 had greater chances to move to the next level of growing into a system of innovation than the other two networks. Network 2 had an opportunity to expand from a platform to develop a niche market into a nexus of stakeholders that enables mass-production of the novel technology as long as the network could provide fairer competitive as well as a co-operative environment between incumbent firm and innovators. Meanwhile, Network 1 may grow from being a platform for knowledge exploration into a hub of stakeholders that aims at creating markets for the novel technology, when leading actors of the network could apply a more bottom-up approach to implement their programs efficiently and effectively because it would enable actors at a grass-roots level to communicate their needs and expectation towards the novel technology. On the other hand, it was possible for Network 3 to evolve from being a platform for knowledge exploration of the novel technology into a nexus of stakeholders that was able to create a niche market, when the network decreased slightly its dependency on support from government-related sponsors by creating more independent joint-projects between universities. In addition, Network 3 had the potential to flourish as long as it had more initiatives to engage in communication with industry and end-users.

9 Conclusions and outlooks

9.1 Main findings

This study aimed at amplifying the technological innovation system (TIS) approach with emerging countries as its specific context. It extended the analysis of previous literature through providing a more bottom-up approach in studying the development of a specific novel technology field by introducing the role of innovation networks as pioneers of the TIS due to their potential to form and operate the functions of the TIS. Through utilizing a mixed research approach and focusing on smart grid technologies in Indonesia, the research analyzes three different types of innovation nexuses between 2009 and 2019 that were dedicated to smart grids. The results show that those nexuses were able to build connections between various collaborative movements and had the potential to create nurturing ecosystems for the novel innovation. Those innovation nexuses included the political decision-based network primarily dedicated to the implementation of government top-down programs with the topic of rural electrification facilitated by the energy policy maker, the business-based network related to green technologies led by the incumbent firm and the knowledge-based network guided by the regulator of the national research and higher education. Nevertheless, each innovation nexus depicted its own characteristics in terms of goal, focus, capacity, achievement and opportunity to move forward to create a new technological regime dedicated to smart grids.

Based on this study, the following conclusions can be drawn:

- (Have there been any collaborative projects related to smart grids in Indonesia which can categorize themselves into different networks, e.g. political decision-based network led by the energy policy maker, business-based network led by the state owned-utility/monopolist/incumbent firm, and knowledge-oriented network led by the research & higher education policy maker? Furthermore, what has the general feature of those movements been so far?)

  Yes. The results based on the calculated value of the social network indices show that collaborative movements within three different innovation networks, in general, were highly decentralized or uncoordinated. Those networks also demonstrated a fairly weak connection among members due to their difficulty in efficiently sharing information and producing partnership agreements. Nevertheless, the network dedicated to rural development that was facilitated by the energy policy maker and the business-based network that was under the wings of incumbent firm had greater capacity in terms of creating collaborative projects, coordinating their movements and sharing knowledge among stakeholders than the knowledge-oriented network that was guided by the research and higher-education policy maker.

- (What are the general characteristics of common resource management practiced by the stakeholders while conducting collaboration projects within innovation networks for smart grids in Indonesia?)

  It is shown that, in general, the power of overall stakeholders to create their own concensus in engaging their collaborative projects within innovation networks was overshadowed by the capacity of a limited number of stakeholders, especially government-related bodies, that dominated the operations of networks.

  The results also illustrate that the level of performance of both the power derived from consensus of overall stakeholders and the interventions of focal actors to develop their networks was still relatively low in contributing to the development of those three networks to build TISs. This situation was contradictive with the necessity of a TIS to have either an adequate level of ‘’ democracy’’ of overall stakeholders to develop and utilize novel technology or a high degree of support provided by prominent actors in order to emerge.

  Nevertheless, each network presented its own specific characteristics in terms of common resource orchestration. The network that was facilitated by the energy policy maker and the business-based network led by the incumbent firm showed greater domination from leading actors within the network. This may hinder the process of those networks in growing into a system of innovation if those leading actors produced policies that created a type of vicious cycle in order to slow down or even stop the movements related to the novel technology. Meanwhile, the knowledge-based network that was guided by the research and higher- education regulator showed its potential to have a greater balance between power of overall stakeholders and authority of a limited number of focal actors in order to develop the network together.

- (To what extent have the potential and actual intervention of leading actors in smart grid activities in Indonesia, e.g., the energy policy maker, the state-owned utility/monopolist/incumbent firm and the research & higher education policy maker, developed or even hindered their own networks?)

  It is shown that the conditions of the three networks that were less centralized and had a frail connection among stakeholders conceivably produced opportunities for a limited number of stakeholders to influence those networks by either controlling the circulation of information or supporting or even hindering stakeholders to continue their movements. This is because those elite stakeholders owned a significant central position within networks due to their economic-social-political power.

Subsequently, it is illustrated that despite their original capacity in informally setting-up their own innovation network, three focal actors, specifically the energy policy maker, the incumbent firm and the regulator of national research and higher education, did not always become the leader or the most powerful actor in their own network. Based on the value of social network indices of those bodies in the period 2009-2019, the energy policy maker had greater potential in intervening in the business-based network initiated by the incumbent firm. At the same time, the incumbent firm had greater possibilities to be the central actor of the innovation network aimed for rural electrification that was initiated by the policy maker. Only the research and higher education policy maker had potential to lead its own network.

Empirically, between 2009 and 2019, besides having a capacity to create the largest amount of movements within its own network and guide them, the energy policy maker was seen to be more involved in governing the business-network that was led by the incumbent firm. It worked hand in hand with the incumbent firm to control or even slow down the development of the niche market of smart grid technologies in Indonesia, especially smart meters for rooftop PV prosumers, through several fiscal and non fiscal policies.

On the other hand, for the same period, the incumbent firm, besides owning the authority either to grant or to deny lincenses related to the adoption and testing of the novel technology within its own network, showed its power in controlling the operation of the network that was begun by the energy policy maker. It conceivably potitioned itself as the main supervisor of the network as well as player of the majority of on-site projects issued by the energy policy maker due to its power as the monopolist (as solely actor that set the price to the end-consumers) as well as the oligopolist (as the single buyer of electricity produced by all type of power generations in Indonesia) of the national electricity sector.

Meanwhile, the regulator of national research and higher education, even though they had the potential to govern its own network by having the highest value of social network indices, it experienced difficulties in supporting its own network effectively due to its limited capacity in terms of financial, political power, and human resources. In this situation, local universities and research centres proved themselves as main players of the network, even though they had a high depen-dency on funding policy from external sponsors, such as the energy policy maker, the incumbent firm, and the finance policy maker.

Apart from those government related focal actors, the research found that smart grid innovators also played a significant role in creating a notable amount of movements aimed for creating niche market for the novel technology. This mostly took place both within the network set-up by the energy policy maker and the business-network heavily influenced by the incumbent firm. This demonstrated the potential of those firms to balance the domination of government-related bodies, especially the energy policy maker and the incumbent firm which belonged to the state, which tended to control the development of most of the innovation networks. In the business-based network, innovators together with early adopters successfully motivated the energy policy maker to issue primary fiscal incentives for the utilization of a certain smart grid technology.

Other findings are that even though the energy policy maker and incumbent firm had the tendency to control the development of the novel technology in order to carefully maintain the current technological regime through fiscal and non fiscal measures, majority of stakeholders from all three innovation nexuses had some dependency on those focal actors. This is because those elite po-werful actors had the reputation, legitimacy, and power in controlling the national energy sector that was needed by most stakeholders in order to conduct their movements. In this context, to be able to engage in collaborative projects with them would be beneficial, because it helped them to gain access to the resources or existing business or political links that belonged to those focal actors. Attaining recognition from local communities would also be easier with aids gained from those prominent bodies.

- (To what extent have collaboration projects related to smart grid within those three networks operated different functions of a system of innovation dedicated to smart grids in Indonesia?)

While the development of a technological innovation system requires stakeholders that are able to simultaneously tackle different activities dedicated to the novel technology, such as knowledge sharing, research, on-site niche projects, lobbyings, capital mobilization, enforcement of fiscal incentives, and creation of legitimation, it is shown that between 2009 and 2019, smart grid movements within three different innovation networks in Indonesia, in general, did not accomplish those requirements. The majority of resources of those nexuses were still dedicated to knowledge exploration about the novel technology. In this context, knowledge sharing and desktop research projects were mostly conducted to get to know about characteristics of the new innovation and its possibility to enter the market in Indonesia. Those findings demonstrate the ability of those ne-xuses that were not yet able to cover multiple tasks synchronously and handle them like components of a machine of system of innovations that work hand in hand to create a virtuous cycle for the novel technology.

In addition, those nexuses were seen to experience rather similar challenges in extending their movements, namely social barriers and lack of political support. The cost of the novel technology that was only affordable for a limited number of the local population and incompatibility of current infrastructure with the novel technology belonged to those social barriers. Meanwhile, challenges related to a lack of encouragement from the government for society to adopt the novel technology included the inconsistency of the fiscal incentives and difficulties of candidates of adopters to gain the license to install it.

Nevertheless, the results show that the business-based network that was under the incumbent firm performed more effectively to gain possibilities to grow into a system of innovation than the political decision-based network led by the energy policy maker and the knowledge-based network dominated by academics. Despite delivering a large amount of its resources to conduct knowledge sharing and basic research, the network supervised by the incumbent also simultanously dedicated a significant amount of assets to implement other functions of system of innovation, such as on-site demonstration projects to test and redevelop the novel technology, mobilization of investment in local areas, and lobbying activities with politicians and the incumbent firm itself. In addition, the network also enhanced communication between heteregenous members in order to accumulate common resources to gain validity of existence of the novel technology in local society. For more details, it was quite able to cover various type of actors, including academics, innovators, local and national governments, incumbent firm, end-users, and private energy consultants. In addition, the network dedicated itself more to types of products that were ready to be tested or commercialized to private users. Meanwhile, the network facilitated by the energy policy maker and the network led by the research and higher education regulator were mostly dominated by academics with basic research or policy research as the major activities.

Moreover, based on the results of the observation of specific on-site demonstration projects conducted under those networks, it is shown that each network performed differently in developing their niche experimentations to grow into systemic movements. Overall, the business network was more successful in creating experimental projects than two other networks. This because it focused more on sellable product. From this point, stakeholders of the network were able to create a business motor to enhance development of a new business related to the novel technology. The motor consisted of several efficient components that connected to each other to build a supportive environment for the new innovation. Those included a significant number of early adopters, the availability of fiscal incentives and lobbying to the incumbent firm and government.

Meanwhile, the on-site niche project that was conducted within the network facilitated by the energy policy maker depicted a situation where a top down government related program that aimed to test the technology did not completely reach and understand the needs of movements done at a grass-roots level. It is shown that to implement more efficient demonstration projects, actors from a grass-roots level required to do negotiations with the energy policy maker about their visions. Through lobbying activities initiated by independent on-site project implementers, the policy maker was able to gain more information about current grass-root movements outside government schemes and to allocate effectively its resources as well as to provide facilitation or legitimacy to those on-site projects.

At the same time, based on the situation of a particular on-site demonstration project within the knowledge-based network guided by the higher-education policy maker, it is shown that initiative and capacity of a limited number of public research centers to create their own permanent facility in order to test and multiply the location of novel technology-testing were among the factors that conceivably influenced the sustainability and success of niche experimentations. The on-site project under the knowledge network created an innovation motor that its components basically worked for knowledge sharing and research activities with less ability to directly conduct any collaboration or communication with policy makers, incumbent firm, innovators and private end-users.

- (What are the specific advantages and disadvantages of each innovation network and what are strategic mechanisms for optimizing its performance as an embryo of the innovation systems for smart grids in Indonesia?)

  Findings indicate that each innovation nexus had its own strengths and weaknesses. It is also demonstrated that those three innovation nexuses were totally different channels that potentially could be used by any green novel technology which was firstly introduced in the international realm, specifically in advanced countries, but aimed at penetrating a new market in a specific but less developed country or region. Nevertheless, it is depicted that the business-based network had greater chances to go to a higher level of process in growing into a system of innovation than the network aimed at the implementation of government top-down programs and the knowledge-oriented network, due to its focus on a sellable product and its ability to prioritize opinion of end-users and create access to engage in negotiation with the policy maker.

  The network facilitated by the energy policy maker was seen as the most powerful network among those three networks, due to the availability of the energy policy maker as the guardian and resource provider of the network. The existence of the energy policy maker as the ''trade-mark'' of the nexus encouraged various prominent national and international bodies, including international banks and other related financial entities, supra national organizations, foreign governments, international NGOs, international firms, and well-known research centres, to join because it was benefitial for them, when they could also access the existing infrastructure or economic-political links that were owned by the energy policy maker. The presence of those prominent organizations made lobbying activities or negotiations with politicians, government or incumbent firm conceivably easier to conduct. In addition, the network could survive in a situation where there was less support from the government and less freedom for stakeholders to engage in coordination or communication in order to enhance diffusion of the novel technology, as long as the policy maker was there to maintain the network at a very minimum level, for example by maintaining contacts with significants players of the renewable energy sector both from a national and international realm. The disadvantages owned by the network, however, included its high dependency on the program or presence of the energy policy maker. It also faced a fairly high domination from various government bodies in implementing its movements. It also had a high possibility that the implementation of top-down programs within the network did not much involve the opinions of stakeholders at a grass-roots level. The findings indicate that there was potential incompatibility between the needs of the local society and the feature of the technology that should be communicated.

Meanwhile, the innovation nexus guided by the regulator of national research and higher-education demonstrated its specific expertise as executors of knowledge sharing and basic research. The network was seen as the right channel to introduce non-sellable innovations that were mostly in the form of ideas or designs. The network, in addition, could survive even without much support from the government, as long as there was freedom given to academics to engage in discussions or knowledge sharing on campuses about the novel technology. The negative aspect found in this network included the limited capacity and lack of focus to develop more commerciable products. It also faced difficulties to engage in relationships with or to gain trust from industry or end-users due to its high concentration on teaching activities with less experience in dealing in business activities. Furthermore, discontinued movements took place within the network due to a high dependency on short term funding schemes from external sponsors. Based on this, any initatives to gain closer contact with industry would be beneficial for the network. In addition, communication and coordination among stakeholders to share a vision was needed to create common long-term visions and resources in order to increase the sustainability of their movements.

At the same time, the innovation network that was under influence of the incumbent firm showed that it was more efficient as a channel for the new innovation to create its local market than other two networks. It focused on managing various activities simultanously in order to expand the niche market by enhancing more competiton and co-operation between innovators and the incumbent firm. In this level, the early adopters, a small number of population with high levels of income, also helped innovators to have a greater bargaining position to gain access to conduct communication and lobbies with the politicians to encourage the penetration of the technology in local market. If there was any significant decrease in price of the novel technology, it was possible that the network could grow faster to be able to create a new business regime because it induced a larger size of population to able to utilize the product. Subsequently, the problem faced by the network included the domination of the incumbent firm and the possibility of distrust between the incumbent firm and the innovators. In this context, the incumbent firm that was not yet ready to face any transformation of the novel technology but had a significant social-political power at a national level may tend to slow down and control the development of the technology. Nevertheless, the creation of a specific joint-venture between innovators and the incumbent firm accompanied by a more consistent but neutral support from the government may enhance the technology to survive and develop to be suitable for the local market.

9.2 Contribution of the study and future research recommendation

9.2.1 Contribution of the study

1. Scientifically, the study contributes to the current literature of TIS by introducing innovation networks as the main instruments to detect the formation and operation of a system of innovation, especially in the context of developing countries. The details are as follows:

    - The research engages critics towards current TIS literature that lack attention towards the process of development of a TIS itself. It demonstrates that the formation process of system of innovation for a new technology field involves various decentralized as well as independent movements that potentially group into different types of innovation nexuses. Those movements work both at a grass-roots and regime level. Furthermore, those movements may have to experience various stages of processes to be able to successfully create a system of innovation.
    - It provides a literature review that explains the network resource management that conceivably influences the performance of innovation nexus. Different modes of resource orchestration and network attributes belong to the element.
    - The research also summarizes various explanations given in literature about the correlation between the existence of leading actors and its impact on network resource orchestration. In this study, the government, the incumbent firm and universities are among the potential leading actors in developing a new technological regime. Subsequently, those actors have capacity either in enabling or hindering innovation processes.
    - It develops a model of evolution of a TIS both at a macro and at a micro level. Analysis at a macro level is undertaken by examining aggregate collective movements of stakeholders within innovation networks, whereas an analysis at a micro level concentrates on a specific entrepreneurial experimentation implemented within an innovation network. .
    - The research offers clear-cut strategies for each distinguished type of innovation network through a scenario analysis.

2. In general, this study provides input to policy makers, innovators, the incumbent firm, end-users and academics related to the topic of diffusion of a new technology in developing countries, especially Indonesia. This may help to develop the construction of innovation policies and technological support agendas in order to expand the market of clean technologies in the country. It develops a model concerning different channels that can potentially be adopted to introduce a novel innovation, especially in emerging countries. Those channels refer to three types of different innovation nexuses, all of which are informal.

- The first channel is an innovation network led by the policy maker. It was quite effective for testing or marketing a novel technology that may be sellable for local people in a limited period of time. The policy maker would conceivably ease the process due to its existing social-political connections and influence toward its population. The disadvantage of this channel includes the high dependency on the political will of the government that defines the sustainability of funding for the network.
- The second channel is an innovation network that needs resources owned by the incumbent firm. This channel is very suitable for introducing new products that are already commerciable or have high possibilities to be sellable in local market. In this context, innovators or new entrant firms may need to engage in relationships with the incumbent firm due to its established business chains and resources. Access to the incumbent firm's business links as well as legitamacy in local society are benefits gained by the innovators. Meanwhile, the incumbent firm has the possibility to learn the novel technology as well as to prepare strategies to survive in a competition with innovators through conducting collaborations or sharing knowledge with innovators within the network before starting a new business that is similar to the innovators. The network may experience problems when unhealthy competition between innovators and incumbent firm takes place.
- The third channel is an innovation network that is formed and operated within the academic realm. It is quite an effective platform to introduce concepts or ideas about disruptive innovations. Those Ideas and concepts of novel innovation may be induced in classes, seminars and laboratory-scale experimentations on campuses. Nevertheless, the output derived from the network may take time since it is aimed primarily at changing the attitude or understanding towards a specific innovation or business opportunity of a large population of students or a potential young generation. Only a top-down program from government or initiatives from both the academic realm and industry can enhance the network to grow faster.

9.2.2 Future research recommendation

This study still has several limitations, especially related to its population size and ability to cover a greater number of on-site experimental projects. In the future, it is recommended to conduct research in regards to the topics found in this study, especially to improve analysis about innovation networks as pioneers of technological innovation systems, as follows:

1. Investigating and comparing the different performance of on-site demonstration projects that are still under the same innovation nexus.

2. Implementing a comparative study about smart grid innovations between Indonesia and other emerging countries, especially in Southeast Asia, or between Indonesia and a particular developed country.

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11 Appendices

11.1 Questionnaire for on-line survey

CARL VON OSSIETZKY universität OLDENBURG

FAKULTÄT II – INFORMATIK, WIRTSCHAFTS- UND RECHTWISSENSCHAFTEN

DOCTORAL PROJECT

Survey of Innovation System Approach for Smart Grid Technologies in Indonesia

Networks for Innovation and Technology Transfer

Objective of the research:

This research aims at studying various involved actors that conduct research, development, and diffusion of smart grid technologies in Indonesia, as well as their interactions and how they manage their networks together. This research is significant because of the possible benefits to provide practitioners and policy makers in increasing effectiveness of innovation movements for smart grid technologies in Indonesia.

Clarification of terms used in this questionnaire:

- Stakeholders/Actors: Any kind of involved entities participate in any types of activities related to smart grid technologies. The research categorizes divided actors into three groups: Provider/Developer/Producer (firms, research centers, schools, universities), User/Customer (Communities, Private/Individuals, Organizations), and Third Party (Regulators/policy makers, financial entities, NGOs, Media, Donors, Consultants, Intermediaries, Installers, Sellers)

- Network: Interactions take place between actors in order to engage activities for smart grid technologies. It may consist of ties that vary in formality. In the research, the terms network, collaboration, cooperation, partnership, affiliation is used interchangeably.

- Innovation and technology transfer activities for smart grid technologies: Activities include idea generation & mobilization, research & development and commercialization of any type of smart grid technologies.

- Innovation System: It is basically a set of actors and their networks involved in research, development and diffusion activities that aims to support or facilitate or reconcile or bridge the all involved elements so that activities such as financing, providing regulation, opening market, guiding/supervising research & development activities and easing resources mobilization are taken place.

- Smart grid Technologies: According to (International Electrotechnical Commission (IEC) 2009), a smart grid is "a digital energy network that can intelligently integrates the actions of all users connected to it - generators, consumers and those that do both in order to efficiently deliver sustainable, economic and secure electricity supplies." Smart grid technologies can also be divided into four categories: (7) information collectors to measure performance of electricity system components (e.g., smart meter), (2) information assemblers, displayers and assessors (e.g., advance electricity pricing, renewable resource forecasting), (3) information- based controller (e.g., smart inverters, microgrid) and (4) energy/ power resources (e.g., virtual power plant.) (Komor et al. 2013; Elzinga 2016; Kappagantu und Daniel 2018)

***Required**

1. Email*

A.1. Your Details

2. What is your name? (optional)

3. What is the name of your organization*

4. Please select the type of your organization based on the category below!

Mark only one oval.

- O Policy Maker
- O Research centres/Universities/Schools
- O Power Producer
- O Non-Government Organization (NGO)
- O Software company
- O ASEAN
- O Financial Entity /Funding Agency
- O Media Company
- O Energy Consultant
- O United Nation
- O Business Association in Energy or Renewable Energy Sector
- O Individual (not belong to any formal organization)
- O Intermediary Insitution/Facilitator
- O other: ______________________

5. Please select your location!

Mark only one oval.

- O DKI Jakarta
- O West Java
- O Central Java
- O East Java
- O Bali- Lombok Island
- O Indonesia - Outside Java-Bali-Lombok Island
- O Outside Indonesia

6. From these three categorized networks/activities for smart grid activities in Indonesia, which are you or is your organization active in? (It is Possible to have more than one answer).

Tick all that apply.

- O Networks/ Activities for smart grid encouraged/initiated/sponsored/coordinated by or linked to the Indonesian Ministry of Energy and Mineral Resources
- O Networks/ Activities for smart grid encouraged/initiated/sponsored/coordinated by or linked to the Indonesian Ministry of Research, Technology and Higher Education
- O Networks/ Activities for smart grid encouraged/initiated/sponsored/coordinated by or linked to the National Electricity Company (Perusahaan Listrik Negara)

A.2. Your Interest in Smart Grid Technologies

7. What type of smart grid technologies based on the category summarized by (Komor et al. 2013; Elzinga 2016; Kappagantu und Daniel 2018) below that might be suitable for Indonesia's situation? (It is possible to have more than one answer.)

Tick all that apply.

- O Advance metering infrastructure (e.g., Smart meter) (''It mitigates lack of distribution monitoring, outage detection and its location, energy conservation and energy theft. It is also capable to provide two-way communication between consumer and the utility").
- O Advance electricity pricing ("It manages high peak loads and load shedding outage frequency through various pricing programs. It signals costumers to adjust their consumption behavior. The information gained from advance electricity pricing could be presented in a smart meter").
- O Demand response ("Systems for reducing electric system loads during peak periods or for load shedding or for managing outage frequency. They include Direct Control Load, Voluntary Load Reduction and Dynamic Demand. In addition, they are more or less depend on existence of advance metering infrastructure").
- O Distribution automation ("It consists of multiple automated control mechanisms aim to optimize the power distribution networks. It mitigates inefficiency; manages voltage regulation and outage frequency and duration so that distribution maintenance costs could be minimized").
- O Renewable resource forecasting ("It tackles reliability issues and cost of wind/solar variability as well as voltage and frequency regulation").
- O Smart inverters ("It handles power quality, voltage/frequency regulation, and undesired inverter tripping offline").
- O Distributed Storage including electric vehicles ("It handles voltage/frequency regulation and power ramps").
- O Microgrid ("It is an autonomous section of an electric grid that supplies its own loads from internal power sources for some period of time. It consists of for example a controller, internal energy sources and an intelligent microgrid switch that handles connection and disconnection from the central grid. A small town, a military base, or a commercial campus could implement this technology").
- O Virtual power plant ("It is a combination of a various distributed energy resources (could be renewable power resources and/or conventional power sources) and energy storages that might not be geographically co-located. They act as a single entity from the grid operator's perspective. The technology is coordinated by software-aggregator or a central controller'').
- O Other: ______________________

8. According to your opinion, please select the current status of smart grid in Indonesia right now in general! (It is possible to have more than one answer.)

Tick all that apply.

- O Phase 1: Basic Research (Aims: to gain general field of knowledge or general theory)
- O Phase 2: Applied Research (Aims: to use knowledge in order to solve a specific/ particular problem; the result must have immediate and clear implications for practice)
- O Phase 3: Prototype Development
- O Phase 4: Demonstration full scale
- O Phase 5: Product Development
- O Phase 6: Market Ready
- O Phase 6: Market Development

A.3. Your Activity Related to Smart grid Technologies

9. Please select your role/your organization's role in activities for smart grid technologies in Indonesia! (It is possible to have more than one answer.)

Tick all that apply.

- O Type I: Provider/Developer/Producer of Smart Grid Technologies
- O Type II: End-User/Costumer of Smart Grid Technologies
- O Type III: Third Party (Intermediaries/network between Type I and Type 11, regulators/policy makers, financial entities, donors, consultants, installers, sellers, independent entities or individuals who have interest in smart grid technologies)

10. What is the focus of project/activity of yours or your organization that related to smart grid technologies in Indonesia? (It is possible to have more than one answer.)

Tick all that apply.

- O Marketing/selling a certain type of smart grid technologies to potential end costumers in Indonesia
- O Analyzing cost and benefit of smart grid technologies in Indonesia from a specific overview (e.g., technical/social/economical/ecological/political)
- O Analyzing regulation (e.g., market regulation, incentives, technical standards, and research & development guidance) for smart grid technologies in Indonesia
- O Analyzing recognition/attitude/perception/response of society in Indonesia about smart grid technologies
- O Conducting pilot and demonstration project of a certain type smart grid technologies in Indonesia
- O Providing financial resources for smart grid projects in Indonesia
- O Working as a mediator/facilitator/information provider for various smart grid - stakeholders in Indonesia
- O Other:

11. How long have you (or your organization) been active or interested in smart grid technologies or involved in commercialization/ technology transfer and innovation activities for smart grid technologies in Indonesia?

Mark only one oval.

- O 0-2 years
- O 3 – 5 years
- O more than 5 years

B.1.1. Your Activities with Other Parties

12. Based on the name of stakeholders below, which one is/are that is/are connected to you (your organization) and your current partnership(s)/collaboration(s) for innovation activities/technology transfer related to smart grid technologies in Indonesia? (It is possible to have more than one answer.)

Tick all that apply.

- O ABB Indonesia
- O Adara Power
- O AEMI (Asean Energy Market Integration Initiative)
- O Allotrope Partners
- O ASEAN Centre for Energy
- O ASEAN-German Energy Program (AGEP)
- O Asian Development Bank
- O Australian- Agency for International Development (AUSAID)
- O *Badan Pengkajian dan Penerapan Teknologi* /BPPT - Indonesia (Agency for the Assessment and Application of Technology)
- O *Badan Regulasi Telekomunikasi Indonesia*
- O *Badan Standarisasi Nasional* /BSN- Indonesia (National Standardization Agency)
- O BAPPENAS/(Indonesian Ministry of National Development Planning)
- O Brawijaya University
- O Business Sweden Indonesia
- O Danish International Development Agency (DANIDA)
- O Dewan Energy Nasional (Indonesia)
- O Energy Conservation Sustainable Solution (enCOSS)
- O Federal Ministry for Economis Affairs and Energy (Germany)/BMWI
- O Federal Ministry of Education and Research (Germany) /BMBF
- O Gajah Mada University
- O GIZ Indonesia (*Die Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) GmbH- *Indonesia)*
- O Global CCS Institute (Global Carbon Capture and Storage Institute)
- O Global Environment Facility (GEF)

- Global Green Growth Institute
- Government of Japan
- Government of United States
- Grenoble University
- HAPUA (Heads of ASEAN Power Utilities/Authorities)
- Hokkaido University
- Indonesia Cyber Security Forum
- Indonesia Power, PT
- Indonesian Institute of Sciences/*Lembaga Ilmu Pengetahuan Indonesia*
- Indonesian Ministry of Communications and Information/DEPKOMINFO (especially *Direktorat Penataan Sumber Daya- Dirjen Sumber Daya dan Perangkat Pos dan Informatika)*
- Indonesian Ministry of Energy and Mineral Resources
- Indonesian Ministry of Research, Technology and Higher Education/*Kementerian Riset, Teknologi dan Pendidikan Tinggi*
- *Institut Teknologi Bandung*
- *Institut Teknologi Sepuluh Nopember (Pusat Unggulan Iptek- Sistem dan Kontrol Otomatis)*
- International Renewable Energy Agency (IRENA)
- Jenderal Sudirman University
- KFW Bank
- Kobe University
- Korean Energy Agency
- KTH Royal Institute
- Kyoto University
- Lampung University
- Lorenzt Indonesia *(PT Inovasi Dinamika Pratama*)
- *Masyarakat Energy Terbarukan Indonesia (METI)*
- *Masyarakat Konservasi & Eflsiensi Energi Indonesia (MASKEEI)*
- MEDCO Energy
- Mercubuana University
- National Renewable Energy Laboratory
- Oldenburg University
- Panasonic Energy

- Pertamina
- *Perusahaan Listrik Negara (Indonesian Electricity Company)*
- *Prakarsa Jaringan Cerdas Indonesia (PJCI)*
- *PT Indokomas Buana Perkasa (OMEXOM INDO)*
- *PT Resco Sumba Terang*
- Pt Synteck Energy & Control
- *PT Unggul Berkah Sejahtera*
- Rambu Energy
- RMIT University
- Rostock University
- Samratulangi University
- *Sekolah Tinggi Tekonologi Nasional Yogyakarta (STTNAS)*
- Sewatama Power
- Siemens AG
- Smart City/ Community Innovation Center- Institute Teknologi Bandung
- Surya University
- The Energy Conservation Centre- Japan
- Tokyo Institute of Technology
- Tokyo University
- Udayana University
- United Nations Developments Program (UNDP)
- United Nations Industrial Development Organization (UNIDO)
- United States - Agency for International Development (USAID)
- United States - Power Working Group for Indonesia
- University of Indonesia
- University of New South Wales
- Winrock International
- World Bank
- National Institute of Aeronautics and Space (LAPAN/*Lembaga Penerbangan dan Antariksa Nasional-Indonesia)*
- Semtech- LORA

- Other:

13. What type of smart grid technologies that become focus on your collaboration(s)/partnership(s)? (It is possible to have more than one answer.)

Tick all that apply.

- None
- Advance metering infrastructure
- Advance electricity pricing
- Demand Response
- Distribution automation
- Renewable energy forecasting
- Smart inverters
- Distributed storage including electric vehicles
- Microgrid
- Virtual Power Plant
- All type of smart grid technologies
- Other:

14. What is the project type of your collaboration(s)/partnership(s) for activities related to smart grid technologies in Indonesia? (It is possible to have more than one answer.)

Tick all that apply.

- O None
- O Scientific project network for smart grid technologies (e.g., research & development project, know how sharing project, and pilot/demonstration project)
- O National/local technical committee for smart grid technologies that prepares technical regulation for smart grid in Indonesia
- O Independent action of citizens/group of individuals who have interest in smart grid technologies and would like to share knowledge about smart grid
- O National network for smart grid technologies (e.g., *Prakarsa Jaringan Cerdas Indonesia*)
- O Business relation in regard to marketing/commercializing smart grid technologies in Indonesia
- O National/local commission for providing non-technical regulation **for** smart grid in Indonesia (e.g., national smart grid research & development planning, incentive for smart grid producer/consumer)
- O Other:

____

15. Where does your collaboration(s)/partnership(s) activities for innovation or promotion/technology transfer for smart grid technologies in Indonesia take place? (It is possible to have more than one answer.)

Tick all that apply.

- O None
- O DKI Jakarta
- O West Java
- O Central Java
- O East Java
- O Bali-Lombok Island
- O East Nusa Tenggara (Nusa Tenggara Timur)
- O Indonesia - outside Java, Bali, Lombok and East Nusa Tenggara
- O Outside Indonesia

16. Since when your collaboration(s)/partnership(s) for innovation activities or promotion/technology transfer for smart grid technologies in Indonesia) had been activated/formed?

Mark only one oval.

- O None
- O less than 2 years
- O between 2 and 5 years
- O more than 5 years

17. What is the current status of your collaboration(s)/partnership(s) (for innovation activities or promotion/technology transfer for smart grid technologies in Indonesia)?

Mark only one oval

- O None
- O Ongoing
- O Finished

B.1.2. Initiation of Your Collaboration

18. Who was the initiator of your collaboration(s)/partnership(s)/network(s) in order to carry out innovation activities or promotion/technology transfer for smart grid technologies in Indonesia? (It is possible to have more than one answer.)

Tick all that apply.

- O None
- O Indonesian Ministry of Energy and Mineral Resources
- O *Perusahaan Listrik Negara (PLN)*
- O Power Producer/Energy Company outside *Perusahaan Listrik Negara (PLN)*
- O Energy Business Association
- O Indonesian Ministry of Research and Higher Education
- O NGOs /Non-Profit Organization
- O Research Centres/Universities/Schools
- O United Nation (e.g., UNDP)
- O Your Organization /Yourself
- O Other: ______________________

19. Did all potential partners actively give contribution (e.g., financial resource/concept/design) during the formation process of your partnership(s)/collaboration(s) (for activities related to smart grid technologies in Indonesia)?

Mark only one oval

- O Yes
- O No, all the assets for the collaboration(s)/partnership(s) came from single or a limited number of stakeholders

20. What kind of contribution that did you or your organization give during the formation of your partnership(s)/collaboration(s) (for activities related to smart grid technologies in Indonesia)? (It is possible to have more than one answer.)

Tick all that apply.

- O Designing the concept of collaboration/partnership (by being supervisor or administrator of the potential collaboration)
- O Providing financial resource to the collaboration/partnership
- O Finding Sponsors/Investor for the collaboration/partnership
- O None
- O Other:

B.2.1. Activities within Collaboration Platform

21. What is the activity(s) of your partnership(s)/collaboration(s) related to research and development (R&D) and knowledge sharing on smart grid technologies in Indonesia? (It is possible to have more than one answer.)

Tick all that apply.

- O None
- O Organizing and/or participating workshops, conferences, seminars and other scientific events (with topic related to Smart Grid) in local /national level
- O Conducting/supporting/engaging/participating/organizing international scientific programs, for example research collaborations, international scientific events, scholarship programs and student exchange programs
- O Conducting investment on R&D activities, for example by creating a research group or conducting a demonstration plant/pilot project
- O Other:

22. According to you, what are some of the challenges in conducting R&D and knowledge sharing on smart grid technologies in Indonesia? (It is possible to have more than one answer.)

Tick all that apply.

- O This topic is not within the area of my expertise, therefore I could not give an answer
- O Lack of effective and efficient coordination/contact/network between research groups/academic institutions, government and industry
- O Lack of complimentary infrastructure (e.g., laboratory, power system infrastructure, internet/Information Technology (IT) infrastructure)
- O Lack of access to finance (when comes to investment for conducting R&D activities)
- O Lack of technical knowledge (including lack of expertise)
- O Lack of trusted/efficient/effective institution to disseminate information or lack of an intermediary body
- O Piracy/Plagiarism
- O Lack of support and/or regulation from the government (e.g., financial incentive, research guidance and technical standard)
- O Lack of continuity /sustainability in conducting R&D for a specific topic (It is difficult to have a long-term project related to smart grid **in** Indonesia)
- O Other: ____________________

23. What is activity(s) of your current partnership(s)/collaboration(s) in regard to introducing or promoting smart grid technologies in Indonesia so that more people know about this new technology? (It is possible to have more than one answer.)

Tick all that apply.

- O None
- O Conducting political debate/ lobbying or negotiation for smart grid technologies in parliament or with local/national politician(s) or with international counterparts
- O Promoting the technology through various types of media (e.g., television, books, newspaper, radio, social media, and internet)
- O Promoting the technology through class lessons/seminar/workshop in universities/schools/research centres
- O Other: ____________________

24. According to you, what are some challenges in regard to promoting smart grid technologies in Indonesia? (It is possible co have more than one answer.)

Tick all that apply.

- O This topic is not within the area of my expertise, therefore, I could not give an answer
- O Lack of access to type of smart grid technologies that suitable for Indonesia's situation
- O This technology is too much expensive (lack of financing)
- O Lack of policy instruments for commercialization (e.g., lack of incentives for users and technology innovators in term of technical and financial)
- O Lack of interest (from point of view of consumers/users)
- O Lack of compatible infrastructure so that it is difficult to install the technology (e.g., IT /internet infrastructure, power system infrastructure, laboratory)
- O Other: ______________________

B.3. 1. Achievement of your Collaboration Platform

25. How was access to collective resources within collaborative project of yours or your organization?

Mark only one oval.

- O Limited, all of accumulated assets/resources or outcomes of collaborative projects were mostly under control of the initiator(s).
- O It was more flexible for involved stakeholders to deploy the common accumulated resources or utilize the outcome of collaborative projects.

26. What is the level of technology appearance that is resulted from your collaboration/partnership platform(s) (for activities related to smart grid technologies in Indonesia)?

Mark only one oval.

- O None
- O In level of different types of ideas, concepts and definitions
- O Selection of first prototypes with availability of a demonstration plant; many of different design/concept now are also acknowledged
- O Scaling up the technology (after successful pilot test, now go to the bigger installation/start to do commercialization)
- O Established product, mass production
- O Other:

27. What is your view on the length or speed of the formation process and performance of your collaboration(s)/partnership(s) for activities related to smart grid technologies in Indonesia?

Mark only one oval.

- O very slow
- O slow
- O normal
- O all speeds

C1. Perception on Factors Lead to a Successful Collaborative Platforms dedicated to Innovation and Technology Transfer Activities of Smart Grid in Indonesia

28. Please rate between 1 and 9 about how important of the following factors to lead to a successful network or collaboration arrangement for innovation and technology transfer of smart grid technologies in Indonesia! (Note: 1= not at all important and 9=very important)

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	Undecided
Having a clear purpose/goal/objective	O	O	O	O	O	O	O	O	O	O
Incentives from the government for technology developer as well as for consumer	O	O	O	O	O	O	O	O	O	O
Availability of Experts to share know-how about the novel innovation	O	O	O	O	O	O	O	O	O	O
Compatibel infrastructure (e.g., Laboratory, power system infrastructure, Information technology (IT) infrastructure)	O	O	O	O	O	O	O	O	O	O
Acceptance/positive attitude of the society towards the novel technology	O	O	O	O	O	O	O	O	O	O
Availability of stakeholder(s) with significant political power	O	O	O	O	O	O	O	O	O	O
Availability of stakeholder(s) with strong financial resources	O	O	O	O	O	O	O	O	O	O
Geographical closeness	O	O	O	O	O	O	O	O	O	O
Equality of right to voice opinion within network/collaboration platform	O	O	O	O	O	O	O	O	O	O
Trust	O	O	O	O	O	O	O	O	O	O
Commitment	O	O	O	O	O	O	O	O	O	O
Clear division of labor	O	O	O	O	O	O	O	O	O	O

Good documentation about each process of development and organization of collaborative projects	O	O	O	O	O	O	O	O	O	O
Availability of administrator/manager in a network/ Collaboration Platform	O	O	O	O	O	O	O	O	O	O
Efficient and effective conflict management within collaboration platforms	O	O	O	O	O	O	O	O	O	O
Clear, affordable and accessible communication within collaboration platforms	O	O	O	O	O	O	O	O	O	O
Availability of intermediaries or bodies that circulate information within collaboration platforms	O	O	O	O	O	O	O	O	O	O

C.2. Experience in Managing Smart Grid Movements within Collaboration Platforms

In this section, please rate between 1 and 9 about the situation of project management within your network(s)/collaboration platform(s) for innovation and technology transfer of smart grid technologies in Indonesia based on your experience! (Note 1=strongly disagree and 9=strongly agree)

29. Spatial Proximity

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	Undecided
Geographically closeness was necessary in order to maintain the efficient communication.	O	O	O	O	O	O	O	O	O	O

30. Power Distribution

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	Undecided
A single or a limited number of stakeholders did not likely dominate the network/collaboration platform.	O	O	O	O	O	O	O	O	O	O
Each party had the same rights to voice his or her voice.	O	O	O	O	O	O	O	O	O	O

31. Trust & Commitment

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	Undecided
Being honest and credible was important in conducting collaboration and all communication events.	O	O	O	O	O	O	O	O	O	O
There was no bad prejudice or anything negatively suspected while conducting cooperation.	O	O	O	O	O	O	O	O	O	O
All of parties fulfilled the task fairly.	O	O	O	O	O	O	O	O	O	O
There was always willing to take a long-term term commitment with the current partners.	O	O	O	O	O	O	O	O	O	O
The parties always thought that the current investment on collaboration with each other was worthwhile.	O	O	O	O	O	O	O	O	O	O
There was adequate understanding and tolerance between parties within network/collaboration platform.	O	O	O	O	O	O	O	O	O	O

32. Coordination & Harmony

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	Undecided
Collaboration(s) was explicitly verbalized, documented and discussed.	O	O	O	O	O	O	O	O	O	O
Division of labor was clearly defined within the network/collaboration platform.	O	O	O	O	O	O	O	O	O	O
Each party or member of network/collaboration platform understood what he or she supposed to contribute during the collaboration.	O	O	O	O	O	O	O	O	O	O
There was an entity that worked as an administrator to manage activities of network/collaboration platform.	O	O	O	O	O	O	O	O	O	O
All parties were working in a complementary manner.	O	O	O	O	O	O	O	O	O	O
Conflicts between parties were resolved efficiency by themselves rather via escalation throughout the wider platform or involving a broad range of external actors.	O	O	O	O	O	O	O	O	O	O
An effective conflict resolution mechanism was in place when there were tensions or disagreements between parties.	O	O	O	O	O	O	O	O	O	O

33. Communication Efficiency and R&D-Technology Transfer Efficiency & Effectiveness

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	Undecided
There was transparency in conducting communication among parties.	O	O	O	O	O	O	O	O	O	O
Communication among parties in the collaboration platform was clear and accessible.	O	O	O	O	O	O	O	O	O	O
There was no problem of knowledge credibility or secrecy in the network.	O	O	O	O	O	O	O	O	O	O
It was important to understand the idea of others clearly.	O	O	O	O	O	O	O	O	O	O
It was easy to identify the relevant persons/intermediaries that was able to circulate and manage the information within the network.	O	O	O	O	O	O	O	O	O	O
Costs for communication within network were affordable or minimized.	O	O	O	O	O	O	O	O	O	O
Leaked information outside collaboration platform was minimized.	O	O	O	O	O	O	O	O	O	O

34. Result in Management Practice

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	Undecided
The time, money, people or other resources invested in collaboration platform resulted comparable output.	O	O	O	O	O	O	O	O	O	O
Sustainability of collaboration platform was also among the important results.	O	O	O	O	O	O	O	O	O	O

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11.2 Interview schedules

INTERVIEW SCHEDULE

Clarification of terms used in this questionnaire:

- Smart grid Technologies: According to International Electrotechnical Comission (IEC) (2009), a smart grid is "a digital energy network that can intelligently integrates the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies." Smart grid technologies can also be divided into four categories: (1) information collectors to measure performance of electricity system components (e.g., smart meter), (2) information assemblers, displayers and assessors (e.g., advance electricity pricing, renewable resource forecasting), (3) information-based controller (e.g., smart inverters) and (4) energy/ power resources (e.g., microgrid, virtual power plant.) (Elzinga 2016; Kappagantu und Daniel 2018; Komor et al. 2013).
- Stakeholders/Actors: Any kind of involved entities participate in any types of activities related to smart grid technologies. The research categorizes divided actors into three groups: Provider/Developer/Producer (firms, research centers, schools, universities), User/Customer (Communities, Private/Individuals, Organizations), and Third Party (Regulators/policy makers, financial entities, NGOs, Media, Donors, Consultants, Intermediaries, Installers, Sellers)
- Network: Interactions take place between actors in order to engage activities for smart grid technologies. It may consist of ties that vary in formality. In the research, the terms network, collaboration, cooperation, partnership, affiliation is used interchangeably.
- Innovation activities for smart grid technologies: Activities include idea generation & mobilization, research & development and commercialization of any type of smart grid technologies.
- Innovation System: It is basically a set of actors and their networks involved in research, development and diffusion activities that aims to support or facilitate or reconcile or bridge the all involved elements so that activities such as financing, providing regulation, opening market, guiding/providing research & development and easing resources mobilization are taken place.

INTERVIEW SCHEDULE TYPE 1

Note:

In this interview, I would like to know about your opinion or perspective as one of stakeholders of smart grid nexus facilitated by the Indonesian energy policy maker.

QUESTIONS

1. What is kind of project of yours or your organization related to smart grid technologies in Indonesia that is within programs of the energy policy maker, and since when it has started?
2. What is the current status of the project?
3. What are the main collaborative activities of the nexus for smart grid that is facilitated by the energy policy maker?
4. What kind of organizations or entities that are mostly active or being involved in the nexus?
5. In general, how were majority of collaborative activities in the nexus created and supervised?
6. As one of stakeholders of the nexus, what are advantages and disadvantages for being connected to or involved in projects within nexus that is facilitated by the energy policy maker?
7. How and to what extent did the energy policy maker intervene the interlinkages among stakeholders within the network?
8. What is actually goal or priority of the energy policy maker in initiating and intervening its network? What is the possible impact to its network?
9. To what extent is the performance of network that is facilitated by the energy policy maker in implementing on-site demonstration projects or activities to acquire the technology or to create demand?
10. What kind of smart grid technology that has been introduced in those activities?
11. Were you involved in the Sumba-microgrid project?
12. If yes, can you explain the historical background of the project?
13. What was the role of the energy policy maker in the project?
14. How did the actors of the project sound and develop their activity and what were their main challenges?
15. How did you see the sustainability or future of the project?

INTERVIEW SCHEDULE TYPE 2

Note:

In this interview, I would like to know about your opinion or perspective as one of stakeholders of smart grid nexus led by the Indonesian state-owned utility/incumbent firm.

QUESTIONS

1. What is kind of project of yours or your organization related to smart grid technologies in Indonesia that has connection with the state-owned utility, and since when it has started?
2. What is the current status of the project?
3. What are the main collaborative activities of the nexus for smart grid that is facilitated by the state-owned utility?
4. What kind of organizations or entities that are mostly active or being involved in the nexus?
5. In general, how were majority of collaborative activities in the nexus created and supervised?
6. As one of stakeholders of the nexus, what are advantages and disadvantages for being connected to or involved to projects within nexus that are facilitated by the state-owned utility?
7. How and to what extent did the state-owned utility intervene the interlinkages among stakeholders within the network?
8. What is actually goal or priority of the state-owned utility in initiating and intervening its network? What is the possible impact to its network?
9. To what extent is the performance of network that facilitated by the state-owned utility in implementing sort of on-site demonstration project or activities to acquire the technology or to create demand?
10. What kind of smart grid technology that has been introduced in those activities?
11. Are you taking part in movement for smart meter PV rooftop prosumers in Indonesia, for example in Jakarta, Banten and Bekasi?
12. What is the main driver of the movement?
13. What is the role of the state-owned utility or maybe the energy policy maker in this movement?
14. How do the actors of the project sound and develop their activity and what are their main challenges?
15. How do you see the sustainability or future of the project?

INTERVIEW SCHEDULE TYPE 3

Note:

In this interview, I would like to know about your opinion or perspective as one of stakeholders of smart grid nexus developed by the regulator of national research and higher- education.

QUESTIONS

1. What is kind of project of yours or your organization related to smart grid technologies in Indonesia that is within programs of the national research and higher- education policy maker, and since when it has started?
2. What is the current status of the project?
3. What are the main collaborative activities of the nexus for smart grid that is facilitated by the research and higher-education policy maker?
4. What kind of organizations or entities that are mostly active or being involved in the nexus?
5. In general, how were majority of collaborative activities in the nexus created and supervised?
6. As one of stakeholders of the nexus, what are advantages and disadvantages for being connected to or involved to projects within nexus that are facilitated by the education policy maker?
7. How and to what extent did the education policy maker intervene the interlinkages among stakeholders within the network?
8. What is actually goal or priority of the education policy maker in initiating and intervening its network? What is the possible impact to its network?
9. To what extent is the performance of network that facilitated by the education policy maker in implementing sort of on-site demonstration project or activities to acquire the technology or to create demand?
10. What kind of smart grid technology that has been introduced in those activities?
11. Were you involved in the microgrid project in Baron techno park?
12. If yes, can you explain the historical background of the project?
13. What was the role of the education policy maker in the project?
14. How did the actors of the project sound and develop their activity and what were their main challenges?
15. How did you see the sustainability or future of the project?

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