Energy Transition in Taiwan: A Multi-level Perspective

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Summary

This dissertation focuses on the issue of a sustainable energy transition in renewable energy (RE) latecomer countries. The importance of sustainable energy transition has drawn our attention because of the fluctuation of energy prices, resource scarcity, and climate change. However, owing to insufficient technological capabilities, economic concerns, and so on, sustainable energy transition may be more challenging for an RE latecomer. For those earlier generations of newly industrialized countries (NIEs), it may prove even more difficult because they have already been locked into a high-carbon society while facing newly emerging countries that are advancing in terms of economic competition. This dissertation takes Taiwan, one of the first generation of NIEs, as the case study. Taiwan has the industrial basis for RE manufacturing and began working on RE deployment around twenty years ago; further, there is a gap between its manufacturing and diffusing of RE. However, the Taiwanese government's energy transition policy since 2016 seems to open windows of opportunity for large RE diffusion and development. This research hence investigates Taiwan's energy transition, aiming to answer the following question: how can an RE latecomer country with an industrial basis move towards sustainable energy transition?

A multi-level perspective (MLP) in transition studies, which distinguishes between three levels, namely, niche-innovations, socio-technical regimes, and socio-technical landscapes, is adopted as the fundamental theoretical framework herein. I first investigate the development of solar photovoltaic and wind power in Taiwan to uncover how the niche for RE has been formed by checking its functional properties, which include shielding, nurturing, and empowering. Subsequently, by studying the nuclear power phase-out decision-making process in Taiwan, I explore how these three levels of MLP have interacted and how the endogenous dynamics within them have affected the unfolding of energy transition.

The results show that for a latecomer country with an industrial basis to move towards energy transition, both domestic and foreign niche may be leveraged to help accumulate the latecomer's capability, particularly to complement the shielding and nurturing functions when the local niche has failed to provide. Regarding the unfolding of the energy transition, the aggregating of the political, economic, and social dynamics in favor of a sustainable energy transition accompanied with the policymakers' leveraging this aggregated timing and conjuncture may open the windows of opportunity for a sustainable energy transition.

This dissertation provides three main academic contributions to energy transition studies using MLP. First, it elaborated on the process of RE development to complement the discussion on the level of niche in MLP, which solved the "technology inherent" presumption issue. Second, when analyzing the unfolding of the energy transition, it identified three groups of actors and extended them as presenting the endogenous dynamics that drive energy transition, which addressed the "lack of agency" criticism of MLP. Third, by investigating the case of Taiwan, a pattern of leveraging the domestic and external niches is specified. This responded to the "spatial narrowness" criticism of MLP while also suggesting that a strategic utilization and the mobility of the elements that constitute the local niche may be a direction for maturing the niche. In addition, these lessons from the case of Taiwan may provide policy implications for those small- and middle-sized latecomer countries that have little leverage (such as a lack of large domestic markets, technological capability, capital and global champion firms) against the global landscape during their governing of a sustainable energy transition.

Keywords: Energy transition, Multi-level perspective, Renewable energy, Nuclear power phase-out, Taiwan

Acknowledgements

> Life is not just pleasure or sadness, but action. Don't forget the original intention, lift your gaze, and you will see the way to go.
>
> —*Biography of A Nobel Laureate: Yuan Tseh Lee*

Ever since I decided to go abroad for advanced studies, life has not presented me with a smooth pathway. I cannot say it was the most rugged compared to others', but the frustrations, joys, valleys, and peaks have taught me that non-linearity exists not only in research but also in life. This has let me appreciate what I have obtained and realize what real happiness is—all of which, I believe, will strengthen me to face the challenges to come.

On April 1, 2011, around three weeks after the Tohoku earthquake (3.11), I arrived in Japan to start my (pre-) graduate studies. I witnessed how Japan has been working on its energy transition after the Fukushima nuclear disaster, an incident that has also impacted Taiwan. Around thirteen years ago, I had a chance to participate in a study abroad trip to Europe regarding policy exchange, where some European professionals suggested that Taiwan can "make a difference in environment to show its difference." Unfortunately, for the past decade, it is hard to say that Taiwan has presented itself with a prominent image on its environmental performance. Regarding energy use, it was not until 2016 that the government fully promoted renewable energy by implementing an energy transition policy. What if this could have happened earlier? Another story would be told in this dissertation.

For helping with the completion of my graduate school programs and this dissertation, I wish to express my gratitude to my academic supervisor Akihisa Mori for his advice and comments on this dissertation and his instruction during the past (more than) eight years, while also taking a *laissez-faire* policy on me during those days. I also thank Akihisa Mori for arranging the setup of the Dissertation Evaluation Committee, and the members of the committee for spending their invaluable time examining this dissertation. Gratitude also goes to my vice supervisors, Makoto Usami, for providing comments on my research in the joint seminars and for his concern of my research progress, and Toru Morotomi for his encouraging talk when we met at the University of Michigan in the summer of 2015, for kindly letting me join his seminars/research meetings which taught me a lot, and for never hesitating to show his support and concern for my progress.

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I am also grateful to Takashi Hattori for hiring me as a researcher for his research project in the final stage of my dissertation writing, which allowed me to stay at the university and continue research work. This became my first job out of my doctoral program and first formal academic job as a researcher. I am especially thankful for his full trust in me and my capability and his respect of my opinions and tolerance of my bluntness during meetings.

A belief that academics and knowledge can change society and make the world better is what has driven me to choose and remain in academia. The completion of this dissertation is just the start of my entrance into the academic world. I am honored to be able to stand on the shoulders of great giants. It is because of them that I can only be humbler and work harder. “All models are wrong, but some models are useful” is probably one of the most important things that I learned that summer in Ann Arbor. I hope that my work thus far and what I will continue to do can contribute, even just a little bit, and make a difference in academia and society.

I would like to dedicate this dissertation to those who have supported, helped and encouraged me along the way, and, to my lovely mother country, Taiwan.

Because of you, I can go so far. Thank you.

Yi-chun Chen 陳奕均
in Kyoto, Japan
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Chapter 1 Introduction

1.1 Energy transition in latecomers

The need to re-examine and adjust our current energy system has increasingly drawn attention over the past few decades due to the fluctuation of energy prices, resource scarcity, and climate change. Many governments have worked on transforming the current high-carbon energy system to a low-carbon one, showing the importance of governing a sustainable energy transition. Turning back to look at the history of energy use, from the perspective of transition studies, due to the pressure to the current energy system and the emergence of new energy options, the transition of the current energy system is inevitable. However, we do not know how fast and when it will happen, and due to the emergence of competing energy options and pathways, it is hard to predict which pathway will be walked through (Verbong & Loorbach, 2012). It might be the phase-out of nuclear power, nuclear power with renewable energies (RE), or carbon dioxide capture and storage. In this dissertation, we work on a sustainable energy transition. We refer to (sustainable) energy transition here as transforming the current high-carbon energy system to a low-carbon, sustainable one, which mainly involves the diffusion of RE and incorporation of a distributed power system. Although RE has shown remarkable growth in the past decade, it has taken around four decades to get to this point (Junginger, Lako, Neij, Engels, & Milborrow, 2012; Raven, 2012). This reveals that energy transition is never an easy task. On the other hand, although the advanced countries pioneered the development of RE and nowadays are still leading in technologies like offshore wind and solar photovoltaic (PV) equipment (Carvalho, Dechezleprêtre, & Glachant, 2017; WIPO, 2017; C.-Y. Wu & Mathews, 2012), the rising RE is also presenting a phenomenal performance in RE latecomer countries, especially in some emerging countries such as China and India. These countries have become global important players in both manufacturing and diffusing wind power or solar PV, while also impacting other countries' RE markets (Carvalho et al., 2017; Y.-c. Chen, 2016; Lewis, 2013).

The introduction of RE in latecomer countries could respond to the expectation of an environmental leapfrogging development, which has been talked about for more than twenty years, and contribute to tackling climate change.[1] However, another aspect reveals that it is more challenging for latecomers to pursue a sustainable energy system. On the one hand, obtaining the RE technology requires the technology (product) and technological capability that can support RE technology. Unless all the physical technologies are going to be imported from overseas, manufacturing capability is required. Even if the latecomer is going to rely on imported technology, capability in operation and maintenance is required, otherwise either the cost for adopting RE might be increased or the usability would be reduced, which may turn out to be a negative effect in the latecomer's employment of RE.[2] On the other hand, while facing employment of poorer cost performance and technological constraints of RE, which makes it unable to compete with other traditional energy sources (although recently this

[1] Given that the main energy source for power generation in some advanced countries such as Japan has usually shifted from a reliance on thermal power to hydropower, hydropower to thermal power, coal to oil, inclusion of LNG and nuclear power (Kikkawa, 2012), the RE installation in latecomers countries in the earlier phase of their economic development is considered to be able to lessen the pollution, compared to a high-carbon relied pathway (Y.-c. Chen, 2016).

[2] Taking Taiwan's wind power installation as an example, the onshore wind turbines were imported from abroad, and even the maintenance and repairing replied on their parent companies, which caused high maintenance costs and occasional long idle time for wind turbines (Apple Daily, 2011; W.-T. Hsu, 2016; C.-K. Huang, 2014; Ou, 2008).

situation is changing), latecomers need to keep pursuing economic growth in order to stay ahead of the new generations of emerging economies. This puts them in a higher pressure position and a dilemma between choosing a cheaper energy or a sustainable but more expensive one, particularly for those that rely on low cost products to sustain their industrial development. In addition, although the idea of leapfrogging claims and expects an early adoption of RE can bring an alternative, cleaner pathway for latecomer countries, some of the RE latecomers, like the first generation of newly industrialized countries (NICs or NIEs), experienced compressed industrialization and have been quickly locked into a high-carbon energy system just as it did in the advanced countries. Hence, the diffusion of RE could be even more difficult in such kind of latecomers. Furthermore, the obtainment of technology and its diffusion is subject to the changing domestic and external environment, and also to globalization, which make those small- and medium-sized countries that rely heavily on foreign trade even more vulnerable.

1.2 Ongoing energy transition in Taiwan

Taiwan has been categorized in the first generations of NIEs (Bozyk, 2006; Arthur P. J. Mol & Buuren, 2003), which experienced economic development and accumulated industrial capability. It undertook addressing the issue of climate change around the same time as the advanced countries, holding the first National Energy Conference in 1998, following the adoption of the Kyoto Protocol in 1997, which later formally initiated the introduction of RE in power generation. However, by 2016, RE constituted less than 5% of Taiwan's electricity generation, of which 2.29% is from RE other than hydropower, while Taiwan's CO_2 emissions per capita ranked 19^{th} in the world, which shows that a transition to a sustainable energy system is urgently needed. When looking to the production and consumption of RE in Taiwan, the deployment wind power is earlier than solar PV. Nevertheless, while failing in nurturing a national or global champion of wind-turbine manufacturer,[3] Taiwan has ranked as the second largest solar cell manufacturing country since 2010. It presents a gap between production and diffusion of RE in Taiwan.

The Taiwanese government announced an energy transition policy in 2016, declaring the phase-out of nuclear power by 2025 and an increase of RE to 20% in its power generation. Although some still question this energy transition policy, the ruling party's push towards this goal has brought a marvelous growth in solar PV annual capacity installation from 360 MW in 2016 to 970 MW in 2018, and attracted major offshore wind power (OSW) developers, such as Ørsted, to invest in Taiwan, which attempt to take their investment in Taiwan as their first stop for expanding OSW investment in Asia (Ihara, 2017a; Jacobsen, 2018). Although in Taiwan, the onshore wind power has been taken as a failure in terms of nurturing the wind power industry, currently the OSW developers claimed that they are confident in local Taiwanese firms' capability, responding to the Taiwanese government's requirement of a local supply chain promise in their OSW projects (P.-C. Huang, 2018).

[3] Although Taiwan has gradually developed wind-power technological capabilities in manufacturing materials and components, which have been mainly exported overseas, mainly to China, the turbines deployed in Taiwan's onshore wind power generation were all imported from overseas. Only one firm, i.e., TECO, has the capability to manufacture wind turbines (W.-T. Hsu, 2016; C.-K. Huang, 2014; Kang, 2018) (see Chapter 3 for further discussion).

1.3 Aims and structure

While Taiwan has faced the changing global environment, such as the impact from shifting world trends and emerging major players regarding RE, and struggled with the dilemma between ecology and economy, which resulted in its still being trapped as a high-carbon society, the case of Taiwan has showed that it performed poorly in RE diffusion while owning an RE technological basis. However, after 2016, there has been a prominent development in RE installation and the scheduled plan for installation. What has caused this "gap" between production and consumption in its earlier RE development and then what has triggered this shift towards a large diffusion after 2016?

One explanation might be changes in administrations or party alternations which bring policy shifts. Rather than being incentivized by economic interests, the pursuit for a sustainable development has usually been the important drive for the development of RE. Hence, to a large extent, the generation capacity of RE comes from political decisions and public policies (Cervigni, 2013). The party change in Taiwan in 2016 from Kuomintang (KMT; Chinese Nationalist Party) to the Democratic Progressive Party (DPP), which brought the announcement of energy transition policy, did play the most important role in triggering the expansion of RE installation. However, when the DPP gained power for the first time in 2000 with its anti-nuclear power stance which attracted the foreign wind power developers to come to Taiwan and positioned RE as one of the measures to implement the "nuclear-power free country" policy, the deployment of wind power turned out to rely on foreign technology and it did not result in promoting RE as a prominent source in power generation. On the other hand, the production value of solar PV in Taiwan shows a prominent growth after 2008, during the period when the KMT returned to power again (2008–2016). While the RE diffusion promotion mechanism, feed-in tariff (FIT), was adopted during this KMT-ruling period in 2010, installation of PV started to have a more significant but steady growth after 2011, and an explosive growth after 2016. Apparently, policy shift resulted from political party alternations may open the windows of opportunity for RE diffusion, but cannot ensure its realization, and hence this cannot answer our question here.

The second possible explanation concerns RE technology itself: Taiwan's RE technology had not been commercially matured enough for large diffusion. This is easily refutable since Taiwan's solar cells have started to be exported to those RE early movers like Germany after around 2005, which means that the maturity and quality of Taiwan's solar PV technology is not questionable. On the contrary, although OSW development is getting matured in some European countries, it is still new to Taiwan. However, the Taiwanese government is promoting the formation of the OSW supply chain and believes that OSW can be one of the important RE sources to support its energy transition policy. This shows that the maturity of RE technology cannot provide as a suitable reason to explain the RE development and the ongoing energy transition in Taiwan.

The third possible explanation is that Taiwan's RE technology, as an export industry, is for export use. This seems to be a good explanation for the PV industry, but it cannot explain why the scale of the wind power industry is much smaller than that of PV, although both have been mainly for export. Moreover, the deployment of onshore wind power in Taiwan adopted foreign technologies such as wind turbines, and only a few components like towers were locally manufactured. Given this situation, why and how could the foreign OSW developers claim that they are confident in Taiwanese companies' technological capabilities and commit to include these companies in their OSW projects?

Policy shifts resulting from party alternations and technological and industrial development are important factors that affect the diffusion of RE. However, it is obvious that each of these factors alone cannot provide persuasive explanations for the phenomenon of RE development and ongoing energy transition in Taiwan. This indicates that a more holistic perspective and long-term observation is needed to explore such an energy transition issue. Thus, by taking Taiwan, a first-generation NIE, as a case, we want to answer the research question: how can an RE latecomer country with an industrial basis move towards sustainable energy transition?

The remaining parts of this dissertation are organized as follows. Chapter 2 presents the literature review regarding environment, economy, environmental technology, and transition studies. By doing this, we come up with the theoretical basis and framework for studying energy transition and point out the detailed research questions of this dissertation. In Chapters 3 and 4, we illustrate specific research frameworks to answer the respective detailed research questions. Chapter 5 is the discussion based on the research question and the answer to it. Chapter 6 concludes with the findings of this dissertation.

Chapter 2 The Literature Review and Research Questions

Energy transition involves the transition of an energy technical system. Since the energy system supports economic and industrial development, such a technological transformation directly touches on the dilemma of economic development and environmental protection which has been discussed for decades in academia and politics.

2.1 Economic development, environmental protection and environmental technology

2.1.1 From "limits to growth" towards green growth

The discourses on economic growth and the environment have been changing. Traditionally, economic growth and environmental protection had been regarded in a negative cycle. The *Limits to Growth* published by the Club of Rome in 1972 warned that unrestrained growth and consumption would eventually cause catastrophic global environmental and social crisis. Contrary to this zero-growth economy concept, some argued that environment issues are a cost to be paid for growth and a problem to be solved, supporting the inverted-U-shaped between growth and environment. Later, the sustainable development discourse, initiated from *Our Common Future* (the Brundtland Report) published in 1987, claims the need for balancing between economy and ecology, and an intra- and intergeneration equity, which set the ground for the following discussions on sustainability (Vazquez-Brust & Sarkis, 2012). After 2000, especially as a response to financial crises, a green growth discourse has prevailed, searching for a way for growth and green to prosper concurrently, while the meaning of green growth has to some extent differed from time to time and region to region (Jänicke, 2012).

To summarize, the relation between environment and economy has no longer been considered a categorically zero-sum game. The following discussion has emerged under this development.

2.1.2 Win-win of economy and ecology: ecological modernization

Ecological modernization theory (EMT), which deals with the interplay of economy and ecology, emerged in Germany in the 1980s. At first, EMT was a political concept rather than a theory. EMT tries to link the modernization driver in advanced economies with the innovation of environmental technology to meet the long-term needs of more environmentally friendly development. EMT pursues a technology-based, innovation-oriented approach to environmental policy (Jänicke, 2008). It optimistically considers that as current environmental problems were caused by modernization, they should and could be solved via modernization. EMT pursues all measures, not just end-of-pipe technology, to foster ecological innovation and its diffusion. In short, it tries to affect the direction of technological change to serve the environment (Jänicke, 2008). However, as EMT emerged in Germany and became more theorized by the participation of Dutch scholars (A. P. J. Mol & Jänicke, 2009), some critics asserted that EMT could only possibly work for countries like Germany and the Netherlands, not for those like the United States. Although some later studies show that EMT also works in latecomer countries (Sonnenfeld, 2000), EMT has been doubted for being based on advanced countries' logic (Fisher & Freudenburg, 2001). Recent discussion on EMT reveals the need for structural change and transition management because of the problems to be addressed such as the N-curve issue, which refers to achievements from technological improvement would be offset by pollution, and the resistance from the losers under modernization (Jänicke, 2008). A radical change, more comprehensive transformation is hence needed.

Regarding globalization, EMT proposed the concept of “lead market” incentivized by eco-innovation as its global strategy and suggested that this EMT in environmental policy could make even small countries show importance in the world (Jänicke, 2000, 2008). Although EMT’s stress on innovation and technology incentive can be considered as a pathway and strategy for industry-based latecomers, their concepts such as lead market and pioneer eco-technology take environmental policy as their prerequisites (Jänicke, 2000), making it unable to explain the phenomenon in Taiwan, i.e. the gap between manufacturing and diffusion of RE technologies.

2.1.3 Promising development pathway for latecomers: leapfrogging

Progress in environmental technologies not only brings the discussion of pursuing a promising win-win relationship between economy and ecology for advanced countries. It also provided the latecomer countries the possibility of an alternative development pathway to “leapfrog” the polluted steps followed in the past by the advanced countries, by deploying cleaner or clean technologies early to avoid the environmental convergence. Goldemberg (1998) coined leapfrog energy technology, claiming the possibility and necessity for developing countries in adopting energy technologies, such as wind power and solar PV, to leapfrog. Unlike EMT, which aims to be included in the guideline for environmental policy and has more systematic discussion in its field, the literature on environmental leapfrogging appears more distracted. Sauter and Watson (2008) explore three different perspectives on leapfrogging: overall development pathway, development and manufacture of new technologies, and early adoption and use of new technologies. To verify the theory with empirical cases in order to search for policy implication for leapfrogging in RE technologies, Y.-c. Chen (2016) summarizes the conditions for leapfrogging in RE and sustainable technologies based on the previous work and applies them to the cases of wind power industry development in China and India. It is shown that the conditions for leapfrogging in wind power conform to those mentioned in previous academic works, while some conditions need more detailed measures, and different governments’ guiding policies would bring different styles of industrial development, although to some extent both of them present the results as leapfrogging in wind power development.

However, these previous studies on promoting leapfrogging RE technologies put more stress on manufacturing while issues regarding the diffusion of RE have been less elaborated. It also cannot provide enough explanation on energy transition which needs both technological change and societal change in order to achieve transformation of the system. Therefore, the leapfrogging concept is not enough for us to study the case of Taiwan, and it seems a broader perspective is needed.

Furthermore, the implications from the cases of wind power development in China and India may have some limitations when applying to small- and middle-sized countries. This is because the large domestic markets in China and India have provided sufficient capacity for installation to trigger the development of the wind-power industry and its diffusion. This market factor not only benefits local companies but also attracts foreign investors that can provide the advanced technologies, while it is not the endowment for small- and middle-sized countries, or, at least a more sophisticated strategy will be needed for them.

2.1.4 From innovation system towards system innovation: transition studies

The studies on sustainable transition can be traced back to the literature on technological change regarding climate change and sustainability (Kemp, 1994; Kemp, Schot, & Hoogma, 1998; Rip & Kemp, 1998). Transformation of the socio-technical system which fulfills our societal functions, such as energy, involves changes not only in technology production but also in the consumption side and those related to it such as cultural, belief and institutions, and so on, meaning that the co-evolution of technology and society is required. Such kind of technological transformation, like energy transition, cannot be explained by studying innovation of a single physical technology, nor can it be understood via a national innovation system or sectoral system of innovation. A system innovation is hence needed to study such a transformation from one socio-technical system to another, which is also called a transition (Geels, 2002, 2004a; Geels & Schot, 2010). The most renowned theory in transition studies is multi-level perspective (MLP) (Moallemi, de Haan, Webb, George, & Aye, 2017; Wieczorek, 2018), which is a middle-range theory that integrates knowledge mainly from innovation studies, evolutionary economics, sociology, and science and technology studies.

MLP distinguishes between three levels: niche-innovations, socio-technical regimes, and socio-technical landscapes. Niches are where novel technologies emerge, such as renewable technology. Regimes are a semi-coherent set of rules carried by different social groups. Regime is characterized by its "meta-coordination" of sub-regimes (culture, policy, science, technology, industry, market, and user preferences) to carry out a certain kind of social function, like energy system.[4] Landscapes represent the external structure or context for interactions of actors. Transitions take place when developments at different levels combine and reinforce one another. MLP considers transition as the following processes: mismatch occurs in the socio-technical regime due to inner or outside pressures [landscapes]; developments at each level align and reinforce one another; the windows of opportunity for niche technology are then opened; niche technology breakthroughs and replaces the prevailing, incumbent technology/regime; and hence eventually transitions take place (Geels, 2002, 2004a; Geels & Schot, 2010; Verbong & Loorbach, 2012) (Figure 2-1, Figure 2-2).

[4] Geels has identified some regimes that are coordinated with and connected to constitute the ST regime. However, he adjusted the contents (composition) of these regimes in his previous works without further elaboration regarding this:

1) Geels (2002) distinguishes seven dimensions in the ST regime: technology; user practices and application domains (markets); symbolic meaning of technology (culture, symbolic meaning); infrastructure; industry structure (industrial networks, strategic games); policy (sectoral policy); and techno-scientific knowledge.

2) Geels (2004a) distinguishes five regimes: technological and product regimes (research, development production); science regimes; policy regimes; socio-cultural regimes (societal groups, media); and users, markets and distribution networks.

3) Geels and Schot (2010) identify six regimes: policy; science; technology; industry (production networks, industry structures); user practices and markets; and socio-cultural regime.

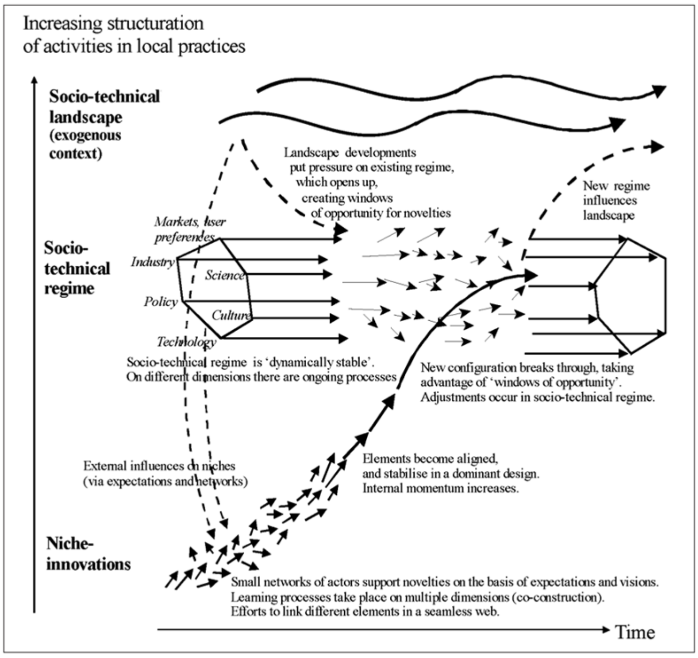
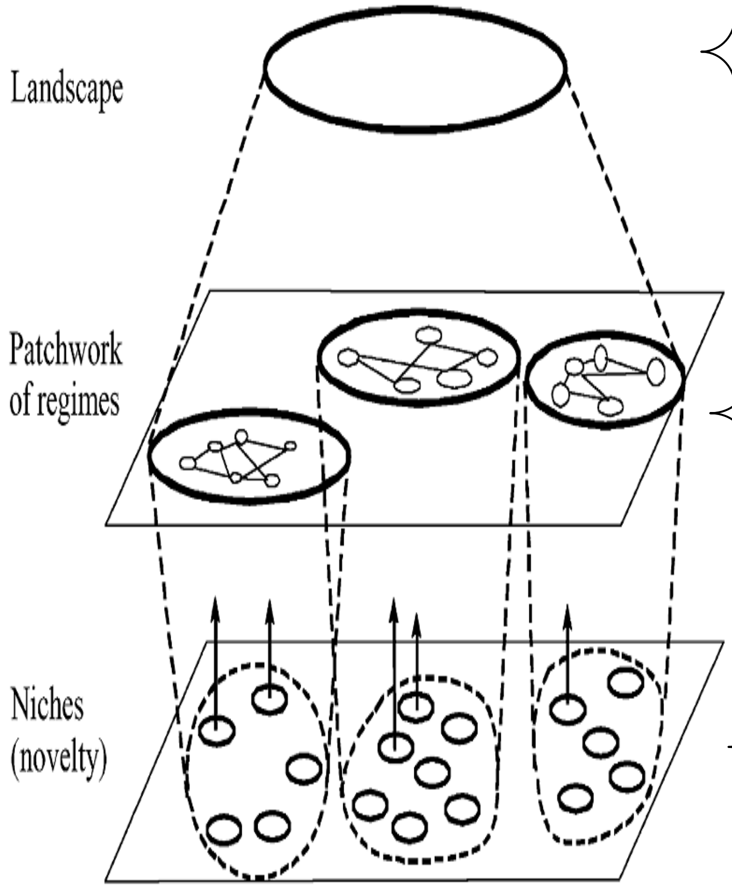


Figure 2-1 Occurrence of a transition under the MLP

Source: Geels and Schot (2010), p.25.

MLP originated in the Netherlands and has been applied to the cases of advanced countries such as the Netherlands, Germany, and the UK. There have been an increasing number of case studies on developing countries using MLP and its related theories (Wieczorek, 2018). Around the 2000s, some works argue that the concepts of sustainable transition, socio-technical system and regime can provide Asian countries an alternative development pathway to avoid the environmental convergence (Berkhout, Angel, & Wieczorek, 2009a, 2009b; Berkhout et al., 2010; Berkhout, Wieczorek, & Raven, 2011). Similar to what leapfrogging has proposed, namely an alternative pathway to skip the polluted steps, they further suggest a broader perspective to be needed by using insights from transition studies, in order to solve the limitation in leapfrogging technology studies. However, these works tend to emphasize the whole economic development, socio-technical regimes or experiments, while there is short of a discussion on the transformation of an energy system and its process here.



Scale	Level	Definition	Explanation
Macro	Socio-technical landscape	• external structure or context for interactions of actors • difficult to change	1. the material context of society, e.g. the material and spatial arrangements of cities, factories, highways, and electricity infrastructures 2. slow-changing factors, e.g. economic growth, emigration, broad political coalitions / changes in political culture and ideologies, cultural and normative values, environmental problems, climate 3. shocks and surprise: rapidly rising oil prices, wars, economic depression
Meso	Socio-technical regime	• semi-coherent set of rules carried by different social groups; inter-group coordination	• linkages between regimes/ "meta-coordination" between regimes (those rules that are aligned to each other [regime]) • "deep structure"/grammar of ST system that are carries by social groups • account for the stability of the ST system • e.g. energy system
Micro	Niche	• where novelty emerges	• to protect new technologies • radical innovations • e.g. renewable energies (RE)

Figure 2-2 Three levels in MLP

Sources: the image on the left is from Geels (2002), p.1261; table contents at the right-hand table are summarized by the author.

2.2 Research questions and analytical framework

2.2.1 Niche formation and a protective space

Taking Taiwan as the case, this dissertation aims to answer the question: how can an RE latecomer country with an industrial basis move towards energy transition? Based on the literature review above, MLP in transition studies is applicable in this research.

According to MLP, a transition of socio-technical system requires the alignment of the niche, regime, and landscape. This means that regarding a technological transformation, the formation and maturity of the niche technology is required while it needs to accompany the regime and landscape in favor of it. However, the MLP theory itself does not elaborate on how the niche technology can be obtained or formed. To address the path-breaking innovations in niches, MLP links to strategic niche management (SNM) to complement itself in developing research frameworks for transition studies theory (Geels & Schot, 2010). SNM proposes that the creation of technological niches, namely a protected space to allow the experiments with the co-evolution of technology, user practices and regulatory structure, can facilitate developing sustainable innovations. The development of these two research frameworks, MLP and SNM, contribute to each other (Schot & Geels, 2008). MLP helps revise early SNM works which proposed a bottom-up, niche-expansion approach to trigger the shift of regimes, and also brings the idea of linkage between different levels to help SNM link to the unfolding of transition. On the other hand, SNM enriches the discussion of niche in MLP. However, although the discussion in SNM suggests the development of local experiment projects and global niche-level during the niche formation, both SNM and MLP tend to presume that the novel technology is a primitive, local-originated one, not one that may be outside of this (country's) ST system. The geographical border between countries are not of concern for discussion. Some previous works also point out this "spatial narrowness" in transition studies (Wieczorek, 2018). This reveals that it ignores the fact that an RE latecomer does not have the technology or sufficient technological capability, which may impact its niche development or energy transition.

Therefore, in order to answer our main research question, we first address the niche formation issue and then turn to the investigation of the interaction between processes at different levels that trigger energy transition. By researching into the development of solar PV and wind power in Taiwan, our first sub-question addresses how the RE niche in Taiwan has been formed and matured the RE technologies to provide the basis for energy transition.

Although the niche discussion in MLP is usually linked to SNM as discussed above (Geels & Schot, 2010; Schot & Geels, 2008), we here apply Smith and Raven (2012)'s explanation on the concept of niche as a protective space,[5] where effective protection should have three functional properties—shielding, nurturing, and empowering—as the basis for us to examine the niche formation.

There are two main reasons that we apply Smith and Raven (2012)'s framework instead of SNM. First, a more flexible framework is needed to address niche formation. SNM emphasizes the idea of experimentation for

[5] In transition studies, niches are defined as "protected spaces" where radical innovations (novelties) emerge (see Geels (2004a); Geels and Schot (2010); Schot and Geels (2008)). In this dissertation, we refer to Smith and Raven (2012) to conduct the analysis (Chapter 3), wherein it is phrased as "protective space," so we primarily use "protective space" as the wording.

nurturing sustainable innovations. This comes from its original interest in the question of why many environmental innovations failed to leave the incubation room and succeed in the market (Raven, 2012; Schot & Geels, 2008; Smith & Raven, 2012). It argues that there are three internal processes for developing a successful technological niche: the articulation of expectations and visions, the building of social networks, and learning processes at multiple dimensions. It develops from a technological niche to a market niche, and finally the niche technology can replace the current regime (i.e., regime shift) (Schot & Geels, 2008). However, the previous studies also show that niche innovation rarely successfully leads to regime shift because external factors are also important to trigger transformation. MLP thus presents as the research framework to link this (niche) internal and external processes. SNM emphasizes the experiment projects where foster the co-evolution of technology, user practice and regulatory structure, presenting itself as a proactive measure, strategic approach to developing the niche for innovative technologies (Schot & Geels, 2008; Smith & Raven, 2012). Nevertheless, although sustainable technologies are usually supported by government in its development, they are not necessarily being provided with well-designed projects by the government. Furthermore, while SNM stresses the setup of internal experiments for developing innovative technology, then combined with the external factors via MLP to illustrate the unfolding of transition, SNM itself is weak in explaining the possibility that the development of technological niche and market niche may be supported by cross-border groups or actors under globalization, which is especially true for those countries relying on foreign trade, positing themselves in global supply chain. Moreover, if sustainable innovation is developed under such a background, what will the niche formation look like and how will it impact the transition? The idea of local experiment in SNM limits such thinking and cannot shed light on niche formation from a more flexible, broader perspective.

Second, SNM only explains one aspect of the niche. Beyond the framework of SNM, although niche, namely the protective space, plays a vital role in transition, surprisingly it has been criticized for a lack of systematic discussion on the concept of protection (Smith & Raven, 2012). The discussion usually focuses on niche’s functioning as the room for shielding and nurturing. What SNM sheds light on is nurturing. However, there is a shortage of explanation regarding how innovations leave the protective space and at this point, what the niche will look like. Given this, in addition to shielding and nurturing, Smith and Raven (2012) hence add “empowering” as one of the functional properties of the protective space, which explains innovation’s interaction with the regime, to help provide a more systematic framework for observing niche.

Therefore, instead of SNM, Smith and Raven (2012)’s proposed framework of a protective space can provide us with a wider and systematic perspective to analyze the development of a sustainable innovation in a country case study. We apply this framework to our research question one, to investigate how the RE niche in Taiwan has been formed and matured the RE technologies to provide dynamics for transition (breakthrough). The analysis of these three functional properties will also provide as materials to link to the storylines in our later analysis of research question two using MLP.

2.2.2 Energy transition and a multi-level perspective

Our second sub-question is: how has the niche RE technology contested with other (mainstream) technologies; and during this process, how have these three levels (namely niche-innovations, socio-technical regimes, and socio-technical landscapes) interacted; and how have the endogenous dynamics affected the unfolding of energy transition? To examine these questions, we investigate the nuclear power phase-out decision-making process in Taiwan. By applying the three-level concept of MLP, we define the landscapes in Taiwan's energy history that affect niche and regime. Coalitions that support different technologies, and dynamics that are represented by different groups of actors are identified to help unveil the energy transition in Taiwan.

Whether nuclear power should be included as one of the energy options in reducing CO_2 for tackling climate change, or whether the relation between nuclear power and RE should be a zero-sum game is not the focus of this research. In this dissertation, we look into Taiwan's pathway towards sustainable energy transition, which we refer to as a transit from a high- to a low-carbon and more sustainable energy system that mainly involves the diffusion of RE and distributed power system. Although nuclear power has been propagated as a zero-emission clean energy source and claimed its safety in utilization, the problem of its environmental sustainability technically (such as nuclear waste) and the "safety myth" make it disputable. We use the nuclear power phase-out decision-making process as the case to observe the contestation between RE and nuclear power in Taiwan's energy transition due to the following reasons. First, the Taiwanese government's current energy policy attempts to make up the power shortage due to nuclear power phase-out with an increase in RE to 20%. Second, through reviewing Taiwan's RE development, we found the contestation between nuclear power and RE, and the ruling party's stance on nuclear power became one of the important factors to trigger the RE development in Taiwan. Last but not least, in terms of the technical aspect, while variable RE has high intermittency and requires a distributed electrical system to support it, nuclear power is easily incorporated into the current conventional power system due to its centralized power supply characteristic.

Chapter 3
Formation of the Niche:
The Development of Solar Photovoltaic and Wind Power in Taiwan

3.1 Introduction

Newly industrialized countries (NICs or NIEs) work hard to catch up with the advanced countries in their economic and industrial development, while facing pressure to tackle climate change issues. This is especially the case for first-generation NICs, including Taiwan, Korea, Hong Kong, and Singapore, which have been already showing remarkable economic growth since the 1970s and '80s and, after the 1990s, been informed on the need to fight global warming, around the same timing with the advanced countries. The same as in other technologies, they are latecomers for renewable energy (RE) technologies. Thus, a protective space for RE technologies, which still have poorer performance, is required in order to help them pass the "valley of death" to reach the diffusion period.

Although NICs and developing countries theoretically have a chance to take an environmental leapfrogging pathway in their development, which is a cleaner path to development than it was for advanced countries, and avoid environmental convergence while achieving economic growth, in reality the situation is more complicated. The development and diffusion of RE may be affected by the ways latecomers obtain RE technologies, by their particular social and political contexts, and by the design and execution of the institutions and measures that are needed for introducing RE. Just as in the advanced countries, protective space is also needed here. However, the current discussion regarding niche or protective space tends to take RE as locally originated, and this ignores the fact that latecomers need RE technology transfer from advanced countries. Furthermore, under globalization, the latecomers have been positioned in the global supply chain, especially for those which have technological capability. This reveals the possibility of the RE technology flow, including not only physical technology but also knowledge and manufacturing.

However, the capability of manufacturing RE does not ensure its diffusion and vice versa. Taiwan has started working on introducing RE in its electricity generation mainly after the late 1990s. However, until 2016, RE (hydro excluded) possessed only around 2.29% of total power generation. Contrary to this low penetration of RE, Taiwan has been the second largest country in solar cell manufacturing in the world since 2011.[6] Wind power industry also started to grow after 2005, though at a much less scale compared to solar power industry. A closer look into the installation of RE in Taiwan shows an early deployment of wind power followed by solar power (Figure 3-1). With the Taiwanese government's announcement of an energy transition policy claiming a goal of 20% of electricity generation from RE by 2025, the major foreign offshore wind power (OSW) developers turned their attention to Taiwan and claimed that Taiwan can be the hub of OSW development in Asia. The situation in Taiwan reveals a gap between the diffusion and manufacture of RE, with different stories in solar and wind power, respectively.

In this chapter, by applying the concept of niche as a "protective space" in transition studies, we will analyze how a protective space for RE has been formed to nurture and diffuse RE in an RE-technology

[6] Taiwan owns a share of 15.9% in production value of solar cell manufacturing in 2017 (overseas manufacturing included).

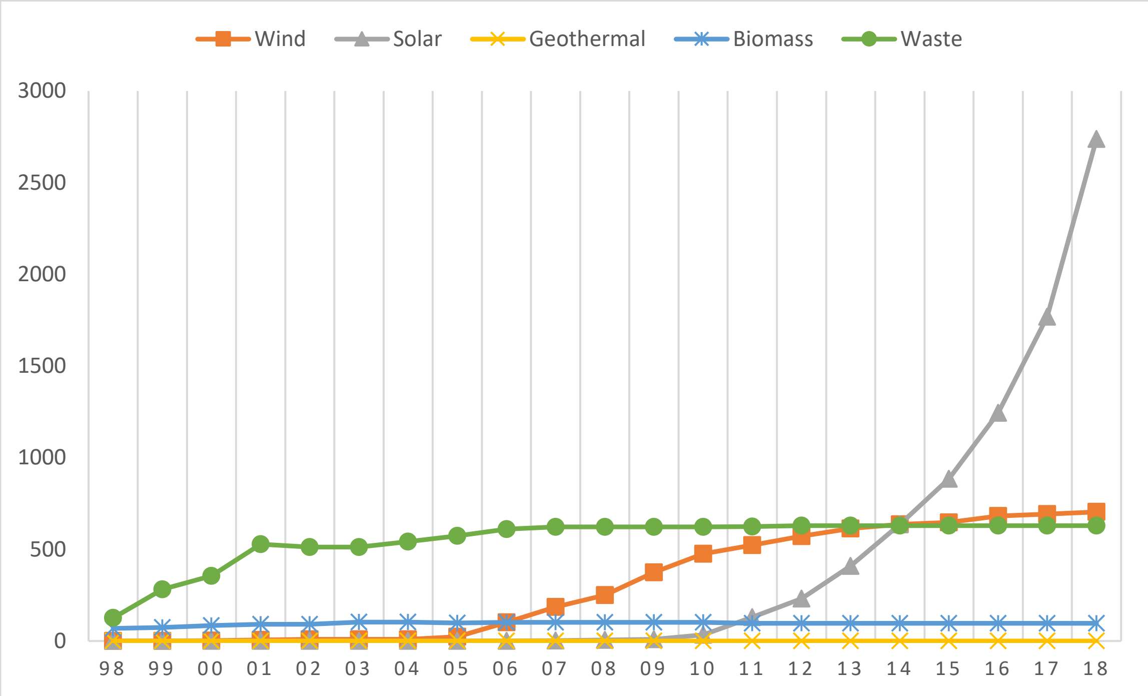


Figure 3-1 Cumulative installed capacity of renewables in Taiwan

(Unit: MW) Source: Data from BOE (2019); chart made by the author.

latecomer country and how the characteristics of such a protective space has influenced the development of RE in Taiwan. By doing this, hopefully we can provide an explanation to the abovementioned "gap" between the diffusion and manufacture of RE in Taiwan. In the next part of this chapter, we will elaborate on methodology and research framework, and then present the solar and wind development in Taiwan, followed by the analysis and conclusion.

3.2 Methodology and research framework

The concept of niche in transition studies represents a space for new technology that still performs poorly and cannot compete with the current dominant technology and market. According to Smith and Raven (2012)'s elaboration on the "protective space," three functional properties can be indicated: shield, nurture, and empower (see Table 3-1 for details). Shield means to keep niche technology, like RE, from the selection pressure of the current environment which is dominated by the mainstream incumbent technology. Nurture refers to efforts to support niche technology development, usually including articulation of expectation, social network building, and learning process. Empowerment represents maturity of niche technology, meaning that the niche technology becomes more competitive under current selection environment without challenging current criteria (called fit-and-conform empowerment), or even, niche technology is strong enough to change and restructure the environment to make it favorable to itself (called stretch-and-transform empowerment). Observing the actors, their networks and narratives involved in this process can help analyze these three functions of the protective space (Kern et al., 2014; Smith & Raven, 2012).

Table 3-1 Functional properties of a protective space (niche)

Property	Definition	Explanation
Shield	Keep from the selection pressure of the current environment	• Mobilize pre-existing support, general founding support • Demonstrations in favorable places • Create financial support, temporary exemption regulation, specific support measures • Tolerate poor technical performance
Nurture	Support niche technology development, usually include articulation of expectation, social network building, learning process	• Learning-by-doing, learning in RD&D, demonstration project • Organize broad coalitions to share positive expectation, show confidence in the technology • Expectation for technological improvement
Empower	Fit-and-conform: make niche tech. more competitive under current selection environment	• Cost down, no need to change current rules/regulations
	Stretch-and-transform: change and restructure the environment to make it favorable to niche technology	• Institutional reform such as electricity reform • Discourse upon shielding as for sustainable value need, nurturing as the learning process toward sustainability

Sources: summarized from Kern, Smith, Shaw, Raven, and Verhees (2014); Smith and Raven (2012); edited by the author.

In order to do this, we compiled the qualitative and quantitative facts to formulate historical events regarding the actors and RE development. The data by which we used to build the "storylines" is mainly from news, interview articles in media, policy announcements, press releases and meeting records/proceedings, and briefing and presentation materials collected from governmental documents, newspaper and news magazine websites and databases, and official websites of related organizations and companies. In the following part, we will first go through the history of solar and wind power in Taiwan, and then identify the involved actors as well as the networks and narratives they use. Finally, this is followed by an analysis of the formation and functions of the protective space and how they affect the diffusion of RE in Taiwan.

Similar research framework has been adopted in researching PV developments in the Netherlands (Verhees, Raven, Veraart, Smith, & Kern, 2013), in the UK (Smith, Kern, Raven, & Verhees, 2014), and in the UK's growing development of OSW (Kern et al., 2014). However, these previous researches only work on a single technology. In this chapter, we analyze both PV and wind power in order to unfold the full picture of the RE niche development in Taiwan.

3.3 The development of solar PV in Taiwan

3.3.1 History of solar PV in Taiwan

(1) Alternative energy and research and development

The research into solar energy began after the oil crises in the 1970s, for the purpose of searching for alternative energies to diversify the energy supply. The earliest research was conducted at the Institute of Nuclear Energy Research, which is affiliated to the Atomic Energy Council (Hwang & Hong, 1984). During 1980–86, in order to meet the needs of the development of semiconductor and solar cells, the National Science Council initiated an integrated project "Silane Project," which included National Chung-Shan Institute of Science and Technology (NCSIST), Industrial Technology Research Institute (ITRI), National Taiwan University, National Tsing Hua University and others, to develop related materials (Hwang et al., 2008; Hwang & Hong, 1984). There were also some firms participating in developing satellite-use solar panel and commercial products of solar cell application (Yang & Tsai, 2005). The development of solar energy is in its R&D phase and for off-grid use.

(2) Climate change, sustainability, and "nuclear-free country": demonstration period

Although Taiwan is not a member of the United Nations, the passage of the Kyoto Protocol and the call for countermeasures to climate change also affected Taiwan and realized the first National Energy Conference in 1998. The Conference concluded that the development of new energy technologies and clean energy is policy of "no regret," which should be given priority. The government promised a budget of 10 billion New Taiwan Dollars (NTD) within five years for research and development and promotion of energy conservation and clean energies. In order to execute the conclusion of the Conference, a taskforce initiated by the MOEA and ITRI with exports and scholars announced the "New Energies and Clean Energies Research and Development Planning Report" which then became the reference for the Taiwanese government's promotion of RE (H.-P. Chen, 2015a; Shih, 2002). This report suggested the government should promote RE based on their respective level in its technical maturity, commercial application, and the condition to industrial development, domestically and overseas. Solar PV and wind power were defined as in the "demonstration" phase. A goal of 3% in total energy supply from renewable energy by 2020 was set. Given this, PV Demonstration Promotion Projects and solar PV power generation system setting subsidy were started after 2000.

Besides, the Democratic Progressive Party (DPP) government, sworn into office in 2000, announced building Taiwan as a "Green Silicon Island" as the vision for this country, which included pursuing a sustainable environment. The DPP's anti-nuclear power position has been part of its party platform ever since its establishment. The Basic Environment Act passed in 2002, including a goal of nuclear power phase-out in the future: "The government shall establish plans to gradually achieve the goal of becoming a nuclear-free country (Article 23)." This has been one of the bases for the government to promote RE. The guidelines for the government are to promote renewables and energy efficiency and strengthen R&D capability to foster clean energy and energy-saving industries (MOEAEC, 2003).

According to the government's analysis and strategy of RE development during 2004–2005, solar PV was positioned as a potential technology, and should strengthen R&D and nurture domestic industry to make it more economically efficient before being diffused. The application of PV was promoted through demonstration projects like solar PV city and selected PV-installed building, PV installation in offshore islands and remote areas. Although there were subsidies for PV installation, personal application for PV installation only possesses 9% of the total installation by 2009 (H.-P. Chen, 2015b).

While the government also noticed Taiwan's industrial development in semiconductor manufacturing can be an advantage for developing PV, the private sector moved even faster. The first solar cell company, Motech, was established in 1999, and then E-ton in 2001. Although the diffusion of PV was slow in Taiwan, the PV industry started to grow after 2000, and experienced a high growth during 2005–2008 (Figure 3-2). This benefited from Taiwan's industrial capability in semiconductor and panel manufacturing, turnkey technology transfer from PV equipment companies in advanced countries such as the US and Japan, and the global demand in solar panels, particularly from Germany. Motech became the 7th biggest solar cell manufacturer in the world in 2006. In 2008, the production value of PV industry achieved 101.1 billion NTD, a share of 11.6% in the global market where solar cell manufacturing ranks fourth globally. In contrast with the prosperous export market, the total PV installation in Taiwan was only 5.58MW (as of 2008).

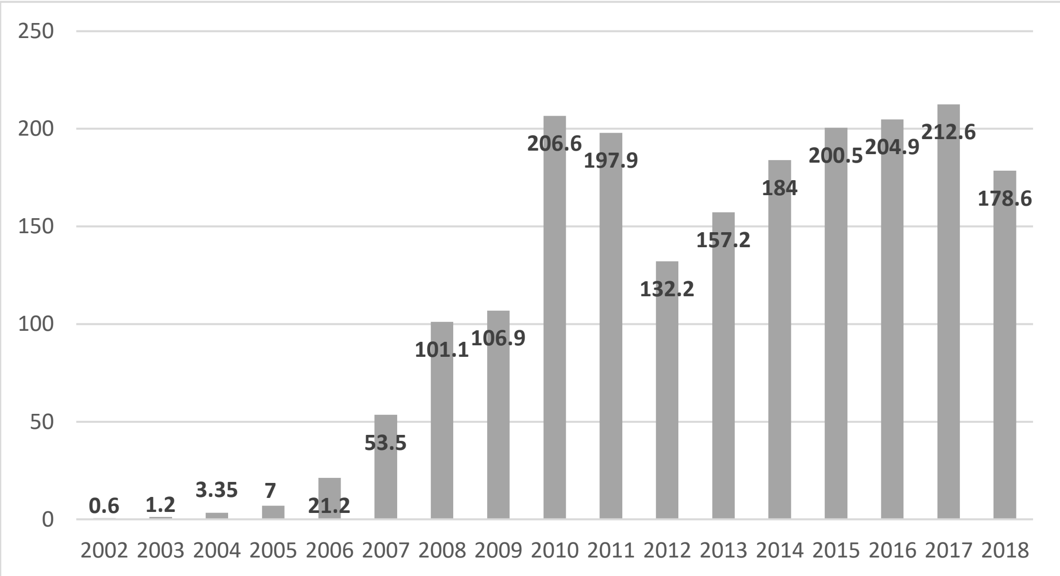


Figure 3-2 Total production value of the PV industry in Taiwan

(Unit: Billions of New Taiwan Dollars [NTD])

Sources: data collected from C.-S. Chen (2008) and IDB (2019) (data provided by ITRI); charted and edited by the author.

(3) Introduction of Feed-in-Tariff and green energy industry: diffusion period

The legal basis for implementing Feed-in-Tariff (FIT) mechanism, the Renewable Energy Development Act, was passed in 2009, after seven years since its draft being submitted to the Parliament for the first time in 2002. FIT was then introduced in 2010, opening the diffusion phase of RE development in Taiwan. A prominent growth of PV installation was observed after 2010 although the government soon, i.e. the second year after FIT introduced, adopted bidding system in order to control the "green gold" rush (Figure 3-3).

Under the global trend of Green New Deal/green growth in the US, Japan, Korea, and other countries, the government declared that Taiwan should quickly position into the international specialization of green industry to obtain a competitive status and hence announced the "Green Energy Industry Sunrise Project" in 2009. Among RE technologies, PV was taken as one of the main RE industries which already has good industrial basis for further development. Based on the government's definition, PV technology was in the growth phase which needs a breakthrough in its technology in order to in prevail in competition with other countries. The goal of this project was to foster Taiwan's solar cell manufacturing to rank within the top three in the world.

Taiwan's solar cell manufacturing value has ranked the second since 2010 (15.8% in global market share), only less than China (47.9%). It is also the main segment in Taiwan's PV supply chain production (65.7% of the total manufacturing value was from solar cell; share of wafer was 16.8% in 2010). Around 90% of this production has been shipped overseas. This makes Taiwan's PV industry vulnerable to fluctuations in international PV product trading, which includes rates of FIT decreasing in other countries and the overproduction and lower-price products from the emerging Chinese PV industry.

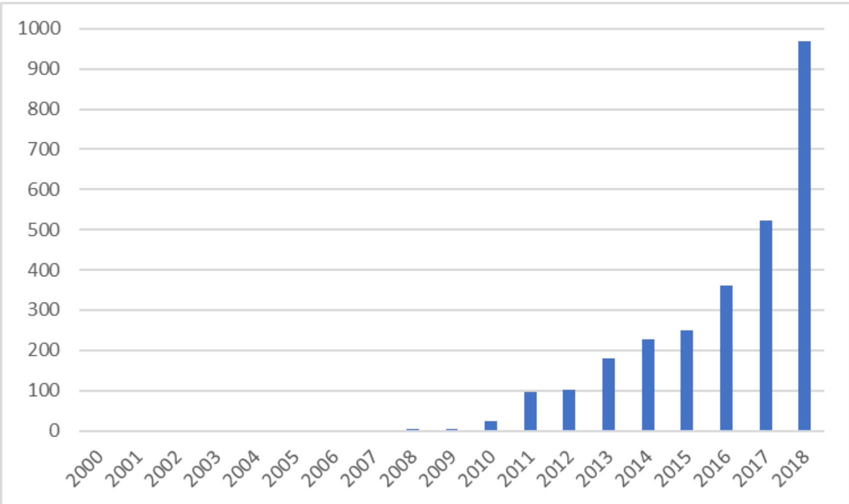


Figure 3-3 Solar PV installation in Taiwan (per year)

(Unit: MW) Source: BOE (2019); chart made by the author.

(4) Fukushima effect: expanding RE installation

Fukushima Daiichi nuclear disaster in Japan (in 2011) also pushed the then-ruling KMT government to adjust the energy policy, announcing the New Energy Policy in 2012, declaring full promotion of RE. "Millions of Solar Rooftop" project was carried out. The government's strategy for diffusing PV was "slow then fast, rooftop then ground-mounted PV." The government also started to promote the energy technical service industry, PV-ESCO, trying to lead more firms to participate in the downstream of the solar PV supply chain. In 2014, the government announced the "Green Energy Industry Jumping Project" to replace the "Green Energy Industry Sunrise Project." The goal was to nurture Taiwan's solar PV system as one of major supplier in the world, further foster the business in solar module and system service.

(5) Energy transition: an ambitious goal of 20 GW installation

The DPP government announced the policy of energy transition and 20% of RE in total power generation by 2025. Given this policy, the goal of solar PV installation was largely increased to 20 GW by 2025, of which 3 GW from rooftop and 17 GW from ground-mounted PV installation. In order to install PV, attention shifts to unused agricultural lands or those that can install applied PV, and citizen's rooftops. In 2018, Taiwan reached over 1,000 MW installation in PV, which records as the most installed capacity in a single year in its history. Benefited from this diffusion, the system segment in PV supply chain has been stimulated, while the solar cell manufacturing is still in its depression mainly due to the fierce competition with Chinese firms and its highly relying on foreign markets (Chang, 2019; C.-Y. Chen, 2019; C.-H. Huang & Hou, 2019).

3.3.2 Actors, networks and their narratives

There are a variety of actors involving in the development of solar PV (Figure 3-4, Table 3-2). Initially the development was initiated by the government and research organization, and more and more actors became engaged as solar technology commercialized and matured. The narratives used by the actors change with the different phases of its development.

The Bureau of Energy (BOE) and Industrial Development Bureau (IDB), both MOEA-affiliated, have been the main governmental organizations in charge of energy policy and energy technology development. They set the plans and policies that directed RE development in Taiwan, coordinated research institutes and companies for R&D and investment in RE technology developing. National Science Council (NSC; now, Ministry of Science and Technology [MOST]) and ITRI were main governmental, or government-funding organizations to work on R&D, with cooperation with universities or firms. ITRI transferred the solar technology to private firms, and some of the PV firms, like Neo Solar Power Energy Corp. (NSP) and DelSolar (incorporated into NSP in 2013) are spin-offs from ITRI. Actors from manufacturing have played a particularly important role since the 2000s, which can be categorized into different segments according to solar PV value chain. Among them, solar cell manufacturers have the largest share in industry value. As the PV further diffuses, more various actors become engaged, especially in the downstream segments of PV industry, investors, electricity generators, and consumers.

Regarding networks, there are three main networks formed to promote PV technology and its diffusion: a) Taiwan Photovoltaic Industry Association which was initiated in 2007 by firms in the PV industry and ITRI, providing as a flatform for industry-academia-and-government collaboration; b) SEMI PV Committee which is set up in 2008 under the global industry association SEMI, an association to promote the development of semiconductor, PV, LED and so on, whose member are from the industry; and c) PV Generation System Association of R.O.C. (PVGSA) which is formed in 2010 to promote the development of PV generation system business.

In addition to the said tangible, formally formed associations related to manufacturing, a broader network formed for PV diffusion can be observed. For example, the first civil RE generator in Taiwan, Taromak Green Energy Corp., was founded under the cooperation between the local community—the indigenous Taromak tribe—and some NGOs (including the Taiwan Environmental Protection Union and Taiwan Renewable Energy Alliance). Sunnyfounder provides the citizens a platform to easily join solar PV investment. Different patterns of business with various actors emerge during the expansion of PV installation.

The narratives applied by the actors reveal the "evolution" of PV technology development in Taiwan, from

R&D to diffusion as one of the main sources for power generation. “Search for alternative energies” after the oil crises opens the R&D phase. “RE as a countermeasure to climate change” revives the government’s attention to solar PV. However, it was still defined as in R&D phase for its “not being economical,” and the application was in “demonstration projects and in remote islands and areas.” PV industry was positioned as an “OEM” industry. Following the global trend of the Green New Deal, the government worked on “fostering the green industry into the global supply chain.” The Fukushima incident pushed the government to adjust the energy policy and announced “Millions of Solar Rooftops” under the government’s strategy for diffusing PV in a “slow then fast, rooftop then ground-mounted” way. Since 2016, the government’s “energy transition” policy supports a full diffusion of RE and encourages the solar PV installation in unused agricultural use farm and citizen’s rooftop (“all citizens generate electricity”).

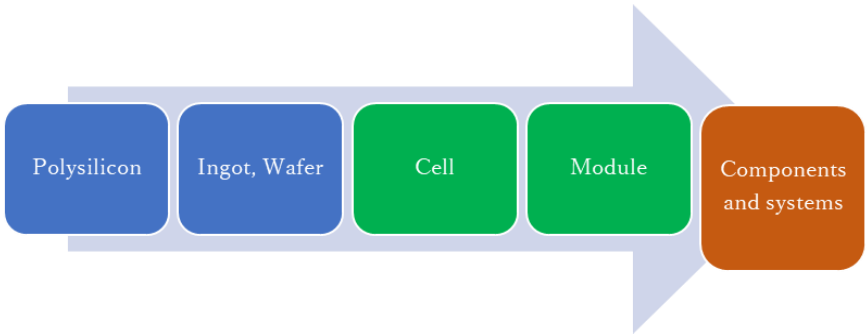


Figure 3-4 Supply chain of solar PV industry

Source: Kang (2018); Kang, Yang, Wang, Shih, and Chen (2017); remade and edited by the author.

Note: The figure only presents the case for c-Si solar cell technology.

Table 3-2 Main actors in PV development

Category	Actor
Governmental department	MOEA (BOE, IDB), NSC
Government-funding organization, governmental research institute	ITRI, National Chung-Shan Institute of Science and Technology (NCSIST), Institute of Nuclear Energy Research (INER)
University	National Taiwan University, National Tsing Hua University
Manufacturer	• Wafer: Sino-American Silicon Products Inc. (SNS), Green Energy Technology Inc. (GET) • Cell: URE (Gintech Energy Corp., NSP, Solartech)*, Motech, E-ton, TSEC • Module: AUO, URE, Gintung, TSEC, Anji
Developer, EPC, Owner	Chailease Finance, Vena Energy, Sinogreenergy, New Green Power, T.E, Solar Master Energy
Financing, investor	• Chunghwa Telecom • Insurance companies (e.g. Cathay Life Insurance)
Generator	• General generators • Other platforms: Green Advocates Energy Cooperative, Taromak Green Energy Corp., Sunnyfounder
Consumer	Large electricity consumers (e.g. Google Taiwan)
Transmission and distribution system operator	Taipower

Note: * Gintech Energy Corp., NSP and Solartech were incorporated as United Renewable Energy Co., Ltd. (URE) in October 2018.

Source: compiled by the author based on the analysis.

3.3.3 Formation of a protective space for PV

The three functions of a protective space are said not to happen in a sequence (Verhees et al., 2013), which means that during one period the protective space may provide different functions. Here we follow the definitions listed in Table 3-1 to find the evidence for each function in Taiwan's PV development.

The government started researching the niche solar energy technology which provided it a shielding space. It also connected to another hopeful industry/technology, semiconductors, as it uses the same silicon material, which made solar technology a co-benefit of such research. The poor performance of PV was tolerated, applying it in off-grid areas or in outer space. The regulations in favor of its development partially come from other preexisting regulations and laws, such as the "Statute for Upgrading Industry," especially during its early development phase.

Regarding nurturing, the government urged R&D in improving the PV technology, providing a bigger budget than in other RE technologies, and supported demonstration projects especially for PV application in governmental and public buildings, which provided a learning space for PV technologies. The government expected that improvement of PV technology can bring the possibility for diffusion in the future. Green industry promotion projects strengthened the expectation in the economic benefit for its export. This echoes to the expectation of the PV manufacturers. The energy transition policy brings a concrete message in promoting PV diffusion, where solar energy is to be taken as one of the main sources for power generation. PV manufacturers utilize this business opportunity to transform their business patterns and to proceed to merge with others in order to maintain competitiveness in the global market (Chang, 2019; Ihara, 2017b). New actors benefit from power generation business, either to participate as a generator or as an investor. The expectation for PV energy technologies becomes stronger and clearer. As to the network, beyond three preexisting industry associations, more and various actors join PV installation, which makes the network expand and extend deeper, presenting the emergence of a broad coalition of solar PV.

R&D efforts are to lower the cost of solar PV to make it competitive in power generation. This reveals that the government has been defining the solar PV development in a fit-and-conform way of empowerment. This can also be explained by the government's principle of a moderate speed (slow to fast) of PV diffusion and promotion of application in remote area and natural disaster damaged area. On the other hand, the introduction of FIT shows that RE was strong enough to change the environment toward favoring its diffusion, although a bidding scheme was soon employed to control it. This stretch-and-transform empowerment was further strengthened after the government announced the energy transition policy. Energy transition was propagated as a "must-do" to support a sustainable energy system and industrial transformation and upgrading which is needed to help Taiwan face degradation of global environment, scarcity of global energy resources, low self-sufficiency in energy, and the citizens' consensus for nuclear power phase-out.[7] Electricity market reform enforced in January 2017 built an environment more favorable for RE than before (by, for example, liberalization in RE power generation and trading, phase-out of nuclear power) (Y.-c. Chen, 2018a).[8] The "all citizens generate electricity" policy measure shows that energy transition policy pushes the government to formulate an environment to make it easier for every citizen to join the solar power generation business, which facilitates the economic benefits trickling down to everyone and accelerates the PV diffusion as well. Furthermore, the demand in "green electricity" also empowers RE diffusion. Google Taiwan said that they could not buy "real green electricity" in Taiwan, which became noticeable news in Taiwan. As one of the policies to fulfill energy transition, the government officially started to issue Renewable Energy Certifications (T-REC). This allowed Google to purchase their first "real" green electricity (from solar power generation) in Taiwan, which was the company's first successful purchase of "real" RE electricity in Asia as well.[9] This news showed that the need for RE diffusion is urgent and a global trend, presenting the value of RE as so important that it can change the environment to favor itself, i.e. the stretch-and-transform empowerment.

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[7] For related discourse, refer to President Tsai Ing-wen's platform of green technologies and sustainable energy policy during her presidential election campaign: https://iing.tw/posts/120, https://iing.tw/videos/72; and the Tsai administration's energy transition related policies:
https://www.ey.gov.tw/Page/5A8A0CB5B41DA11E/f0c0d485-a977-40cc-aeab-5e19e210fd85,
https://www.ey.gov.tw/Page/5A8A0CB5B41DA11E/2ae8bfb8-6014-49d1-b04e-75374fbd6096. (retrieved July 1, 2019)

[8] The content of "nuclear power phase-out by 2025" in Article 95 has been removed from the Electricity Act Amendments because of the outcome of the referendum (the so-called "use nuclear power to nurture green energy" referendum) held on November 24, 2018. However, this does not change the ruling DPP government's policy toward phasing out nuclear power (LY, 2019).

[9] CNA (January 24, 2019), "Google finally bought green power, and the government helped." Retrieved April 24, 2019 from https://technews.tw/2019/01/24/taiwan-helped-google-finally-buy-green-electricity/

3.4 The development of wind power in Taiwan

3.4.1 History of wind power in Taiwan

(1) Search for alternative energies: experiments and R&D

Taiwan started developing wind power in the 1960s as a way of finding an alternative energy source for power generation in the remote Penghu Islands due to the high cost of fuel. Taipower sent staff to join a UN conference on new energies in 1961 and brought information and material from Denmark (J.-Y. Chu, 2008; T.-M. Wu, 2012).[10] Taipower made a Taiwan Wind Power Project and produced a 50 kw wind turbine in 1965, Taiwan's first experimental wind turbine. Due to low efficiency and lack of economic incentive, it was discontinued. The oil crises pushed the government to show interest in wind power, and the MOEA had the ITRI research wind turbines. Three types of turbines—4 kW, 40kW, and 150 kW—were developed, of which 80% Taiwan made and supported (Chiang, 2008). However, due to a lack of economic benefits, the R&D was stopped. Taipower continued to try to find alternative energies in power generation, then set up two 100 kW wind turbines in Penghu made by Windpower Company of the US (J.-Y. Chu, 2008; T.-M. Wu, 2012).

(2) Response to climate change and anti-nuclear power: demonstration projects and private participation

Following the government's policy to address global warming and the announced "New Energies and Clean Energies Research and Development Planning Report" in which wind power was defined as being in the "reward and demonstration phase," the government issued the "Regulations Governing Wind Power Demonstration System Setting Subsidies" to subsidize wind power demonstration projects. Three demonstration projects were finished during 2000 to 2003, including Mailiao Wind Power Demonstration System by Formosa Petrochemical Corp., Taipower's demonstration project in Zhongtun Township, Penghu, and Andante Wind Power Demonstration System by Cheng Loong Corp.

Anti-nuclear power is another incentive for RE wind power development after 2000. Although the ruling DPP, which has an anti-nuclear power stance, failed to stop the new nuclear power plant construction plan (the Fourth Nuclear Power Plant, or FNPP), with the passage of the Environment Basic Act which includes a vision of a "nuclear power-free country," national meetings on a nuclear power-free country were held. The government announced a goal of 10% of RE in power generation by 2010, speeding up the plan for RE deployment as the same goal, i.e. 10% of RE, had been set to be achieved by 2020. Wind power was defined as a "mature" technology to be promoted in the short term according to the MOEA's "Renewable Energy Development Strategy and Measure," in comparison to PV defined as a technology with development potential that in this phase needs more R&D and nurturing of domestic industry. The state-owned Taipower started to purchase renewable electricity from private companies in July 2004, which was the opening of the promotion phase of wind power in Taiwan to the private sector to participate. DPP's anti-nuclear power position attracted foreign investors of renewables, such as InfraVest, a Germany wind power developer, which became the main actor in Taiwan's wind power market (J.-C. Hsu, 2006; Y.-C. Liu, 2009). An obvious growth in wind power installed capacity can be observed after 2005 (Figure 3-5).

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[10] In the material referenced, the conference name is not clearly mentioned. Based on the author's search, the conference might have been the United Nations Conference on New Sources of Energy: Solar Energy, Wind Power and Geothermal Energy, Rome, August 21–31, 1961.

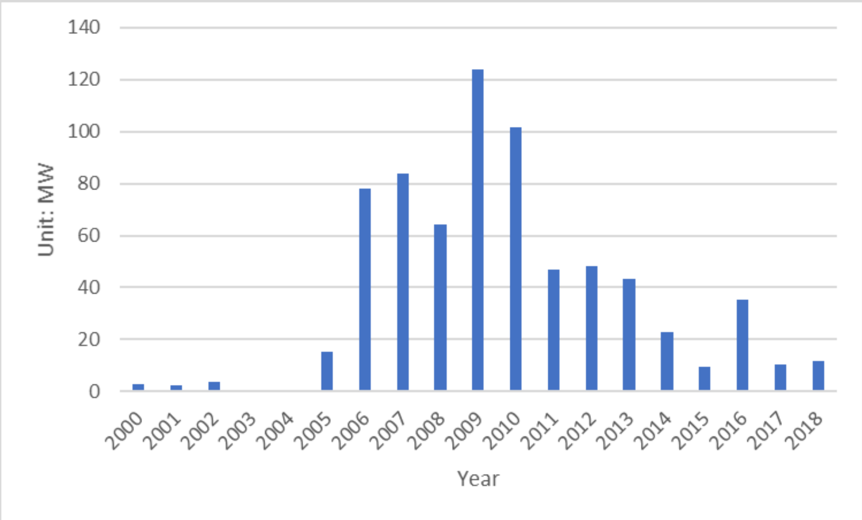

Figure 3-5 Wind power installation in Taiwan (per year)

Source: BOE (2019); chart made by the author.

(3) FIT, green energy industry, and the Fukushima incident: diffusion and the shift towards OSW

The trend of the Green New Deal and green growth urged the government to announce the Green Energy Industry Sunrise Project in 2009 to promote RE technology industry development in order to position Taiwan in the global supply chain of RE technologies. Taiwan's wind power industry was defined as being in the R&D phase and having low penetration in the market but was seen to have the potential of industry development. It was in its period of introduction into the market and lacked core technologies in its industrial development. The government set the goal of promoting Taiwan as one of the wind power system suppliers.

The introduction of the FIT scheme in 2010 opened the diffusion phase in Taiwan's RE development. A vigorous market not to be controlled by Taipower in setting the purchase rate was expected by the private wind-power electricity generator. However, the private firm InfraVest was not satisfied with the FIT rate announced by MOEA. There has not been big change in the wind power generator market, still presenting as a market possessed mainly by Taipower and InfraVest.

The Fukushima incident in 2011 pushed the government to adjust the energy policy to "fully promote RE." Given this policy, the government announced the Thousand Wind Turbines Promotion Project in 2012. Following this, and due to the limited sites for onshore wind farms, the government turned its attention to OSW, passing the regulations for demonstration reward projects (Offshore Demonstration Incentive Program) in 2012. Three projects were permitted: Formosa, Fuhai, and Taipower. The Guidelines for Offshore Wind Farm Site Application was announced in 2015 for further participation in the offshore wind farm development from the private sector. On the other hand, the Green Energy Industry Sunrise Project was replaced by the Green Energy Industry Jumping Project in 2014, in which wind power was listed as one of the main industries to be promoted. The vision was to nurture the technological capability of local construction and operation and maintenance, especially for OSW.

(4) Energy transition: initiating the era for OSW

The government announced an energy transition policy in 2016 in which it will increase the share of RE to 20% in total electricity generation by 2025. The installation of wind power is planned to be increased from 647 MW (in 2015) to 1200 MW for onshore wind power, and 3000 MW for OSW. The government later increased the goal of OSW to 5500 MW in order to take in more foreign investments that have been attracted to Taiwan due to the attractive rate of FIT. The government promoted OSW through a three-phase strategy (Figure 3-6). In phase one, demonstration rewarding projects are opened for application to incentivize participation in OSW development. In phase two, potential sites are opened for application, which include a selection procedure and an auction procedure. OSW developers in the selection procedure will be awarded the preferential FIT rates on the condition they promise a supply chain plan employing local contents or cooperation. In the auction procedure, OSW capacity is opened for auction and allocated to bidders providing the lowest prices. A total of 5500 MW capacity was allocated in 2018 and is planned to connect to the grid by 2025 (Table 3-3, Figure 3-7).[11] Phase three is zonal development which aims to establish OSW industry based on the capability established during the previous two phases.

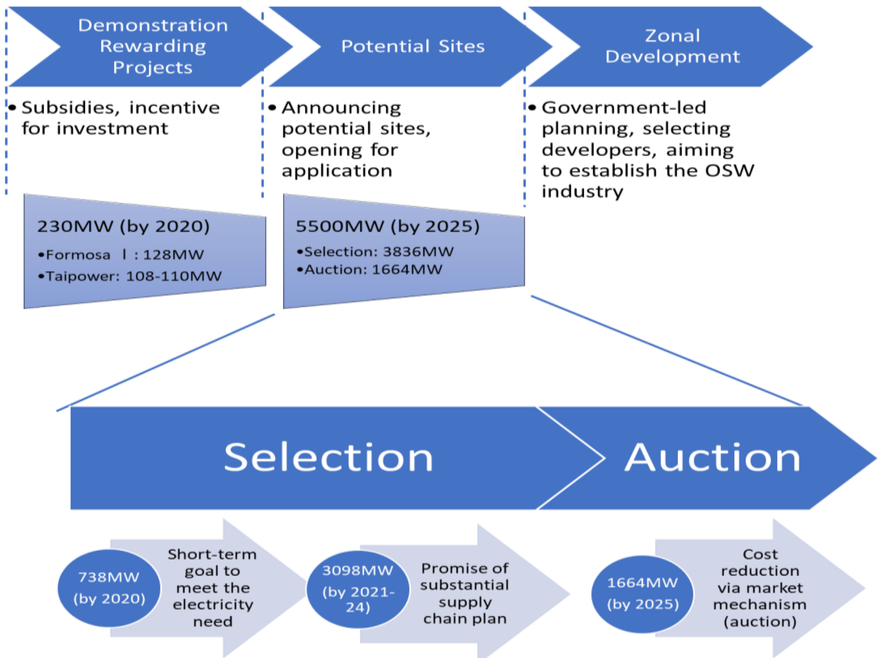

Figure 3-6 Strategy for OSW development in Taiwan

Note: Years represent the years of grid connection.

Sources: BOE (2018); charted and edited by the author.

[11] The years of connection vary because of the government's requirement and the developers' promise.

Table 3-3 OSW developers and capacity allocation in Taiwan

Area	Developer	Wind farm	Demonstration & Selection			Auction		
			Capacity (MW)	Year of grid connection	FIT rate	Capacity (MW)	Year of grid connection	Bid price
Taoyuan	wpd	Guanyin	350	2021	TBD	--	--	--
Miaoli	Swancor+ Macquarie	Formosa II	378 (376)	2020	5.8141 (7.0622/3.5685)	--	--	--
	Swancor	Formosa I [Demonstration]	128	2019 (tentative)	6.0437 (7.4034/3.5948)	--	--	--
Changhua	Ørsted	Greater Changhua Southeast	605.2	2021	5.5160 (6.2795/4.1422)	--	--	--
	Ørsted	Greater Changhua Southwest	294.8	2021	5.5160 (6.2795/4.1422)	337.1	2025	2.5480
	Ørsted	Greater Changhua Northwest	--	--	--	582.9	2025	2.5481
	Yushan+NPI	Hai Long II	300	2024	5.5160	232	2025	2.2245
	Yushan+NPI	Hai Long III	--	--	--	512	2025	2.5025
	CIP	ChangFang	552	2021[100MW], 2023[452MW]	6.2795/4.1422	--	--	--
	CSC	Chong Neng	300	2024	6.2795/4.1422	--	--	--
	CIP	Xidao	48	2024	6.2795/4.1422	--	--	--
	Taipower	Taipower	300	2024	TBD	--	--	--
	Taipower	Taipower Demonstration [Demonstration]	108-110	2020	TBD	--	--	--
Yunlin	wpd	Yunlin	708	2020[360MW], 2021[348MW]	5.8141 (7.0622/3.5685)	--	--	--
Total			Demonstration 230MW + Selection 3836MW			Auction 1664MW		

Notes: "--" represents "not applicable"; unit of FIT rate/ bid price: NT$/kWh (NT$1 is roughly equivalent to US$0.0322 as of October 2019).

Sources: MOEA and news articles; summarized by the author.

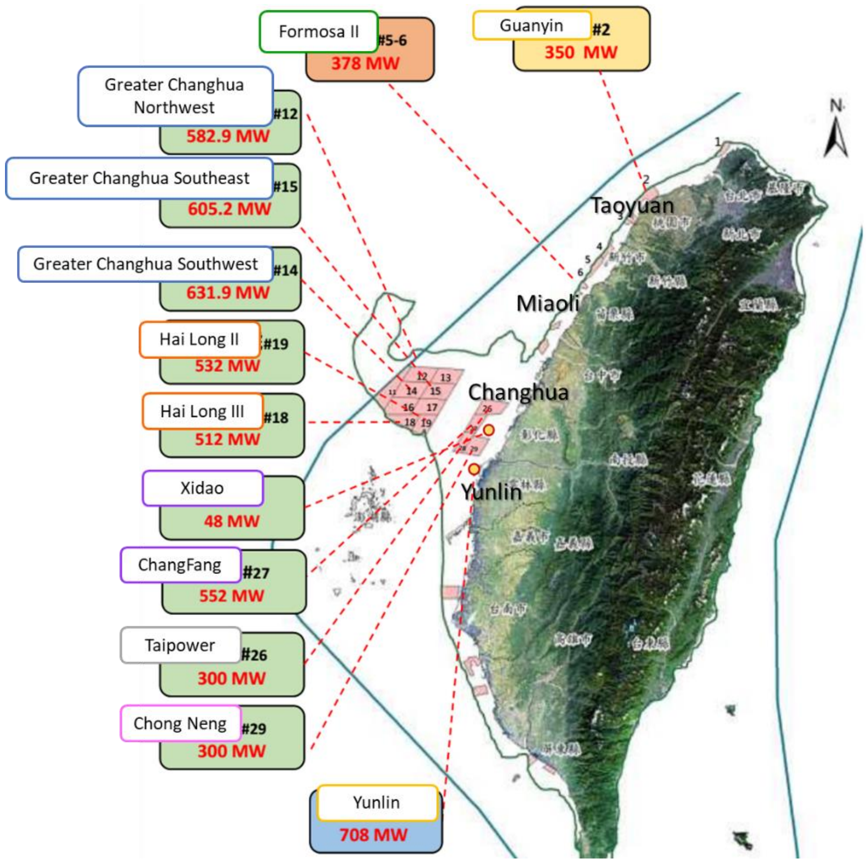

Figure 3-7 Allocation of OSW capacity for potential sites

Source: BOE (2018); edited by the author.

3.4.2 Actors, networks, and their narratives

The development of wind power in Taiwan can be separated into two phases: onshore and offshore wind power development. Regarding the narratives during the development of onshore wind power, searching for an alternative energy for the outlying islands and, later, to replace oil after the oil crisis was the initial thought driving the government and Taipower to look into wind power. Since the late 1990s, developing clean energy to tackle climate change has been the momentum of the government towards promoting wind power. That wind power is a relatively "maturer" RE that can be diffused was then acknowledged in the government's policy planning. After 2000, deploying RE, including wind power, became one of the measures to fulfill the policy goal of nuclear power phase-out. The government also considered that deploying wind power can bring business opportunities and foster the related equipment industry of wind power. On the contrary, this "economic" narrative is less observed in the private developer, InfraVest. InfraVest was attracted to Taiwan around 2000 because they noticed the then ruling DPP's anti-nuclear power stance and were satisfied with Taiwan's good wind speeds (J.-C. Hsu, 2006; Y.-C. Liu, 2009). "No pollution, clean energy" is their narrative when promoting wind power in Taiwan (C.-H. Liu, 2007; J.-T. Wang, 2005). However, InfraVest later felt frustrated by the "unfriendly" administrative procedures, especially environmental assessment, that could delay or even overturn the construction projects (Feifel, 2007; J.-C. Hsu, 2006). Furthermore, the FIT mechanism had failed to pass in the parliament for years, leaving InfraVest no choice but to accept the purchase rate decided by Taipower (Y.-C.

Liu, 2009). In order to maintain their business in Taiwan, InfraVest's narratives accordingly turned to include that the Environmental Protection Administration (EPA) and the Taiwanese government do not welcome RE development, and InfraVest even threatened to withdraw their investment in Taiwan (Feifel, 2007; K.-L. Huang, 2009; InfraVest, 2009; Kung & Lin, 2009).

The BOE, IDB, and EPA were the governmental departments most involved in wind power development (Table 3-4). BOE set the energy policy while IDB worked on developing the industry. The government (IDB) used industrial cooperation program (ICP), which requires foreign contractors to promise a certain percentage of the amount of their procurement to invest, purchase, or transfer technology to local companies in order to help promote Taiwan's wind industry. The government commanded this only in the state-owned Taipower projects. However, these programs still benefited some firms, such as CSC, Formosa Heavy Industries Corporation, and Atech Composites to obtain the technologies from foreign firms. IDB assigned the Metal Industries Research & Development Centre (MIRDC) to design the strategy for promoting the wind-power equipment industry. ITRI is another governmental funding research organization working on R&D and connecting Taiwanese companies that can be included in the wind power supply chain. Regarding developers, the onshore wind power market in Taiwan was dominated by Taipower and InfraVest (Table 3-5). The state-owned Taipower was subject to the government's policy goal of promoting RE, while InfraVest was driven by economic interests. InfraVest only adopted Enercon's wind turbines, while Taipower deployed turbines from different manufacturers in different projects (see Appendix II). Different contractors undertook Taipower's wind-power projects. Toyota Tsusyo Corp. (TTC), a subsidiary of a Japanese trading company in Taiwan, also cooperated with Taiwan's Total Industrial Ltd. to set up the sale agency of Vestas' wind turbines, i.e. Vestech Taiwan Corporation, and largely engaged in turbine procurement and the ICPs.

Table 3-4 Main actors in onshore wind power development

Category	Actor
Governmental department	MOEA (BOE, IDB), Environmental Protection Administration (EPA)
Government-funding organization, governmental research institute	ITRI, Metal Industries Research & Development Centre (MIRDC)
Developer	Taipower, InfraVest
Contractor	• Sinotech Engineering Consultants, Ltd., Star Energy Corporation (SEC), Aerospace Industrial Development Corporation (AIDC), Luxe Electric Co. Ltd. • Toyota Tsusyo Corp. (TTC) / Vestech Taiwan Corporation
Turbine and components manufacturer	• Enercon, Vestas; TECO • CSC, Formosa Heavy Industries Corporation, Atech Composites
NGO/civil group	Yuanli Anti-crazy windmills
Transmission and distribution system operator	Taipower

Source: summarized by the author based on the analysis.

Table 3-5 Developers (owners) of Taiwan's onshore wind farms

Owner	Number of wind turbines	Total installation (kW)	Share in total capacity
Taipower	169	293,960	42.67%
InfraVest (now incorporated into wpd)	145	329,300	47.80%
Challenger Emerging Market Infrastructure Fund Pte. Ltd (EMIF)*	25	49,800	7.23%
Tung Ho Steel Enterprise Corp.	5	11,500	1.67%
Formosa Heavy Industries Corporation	4	2,640	0.38%
Cheng Loong Corporation	1	1,750	0.25%
Total	349	688,950	100.00%

Source: summarized from Appendix II by the author.

Note: * EMIF owns Miaoli Wind Power Co., Ltd since 2013, whose wind farms were first built and operated by InfraVest in 2006 and then acquired by Macquarie (MIIF) in 2008.

Besides the MOEA, ITRI, and MIRDC, which engaged in the accumulation of technological capability and formation of the supply chain, the government supported the setup of associations to gather related firms, which helped with networking and promoting the wind power industry. These associations include Wind Power Equipment Industry Association, which was set up in 2005, supported by MIRDC and succeeded by Taiwan Wind Industry Association in 2011; Taiwan Wind Power Council setup in 2006; and Taiwan Wind Power System R&D Alliance in 2008, supported by ITRI.

However, Taiwan's supply chain formation and technological capability failed to catch up or be incorporated in the wind power diffusion, and Taiwan did not establish a Taiwanese national or global champion wind-turbine manufacturer, nor did many of the local contents employed in the supply chain. All deployed wind turbines were imported from overseas (Table 3-6). Only the towers and a few components were made by Taiwanese firms (C.-K. Huang, 2014).

Table 3-6 Share of wind turbine manufacturers in Taiwan's onshore wind power

Turbine manufacturers	Total installation (kW)	Number of wind turbines
Enercon	435,600	209
Gamesa	12,000	6
GE	39,000	26
Vestas	160,350	87
Zephyros	42,000	21
Total	688,950	349

Source: summarized from Appendix II by the author.

Because of the limited onshore sites suitable for developing wind farms, and disputes with local people over setting up wind farms, the government and wind-industry firms started to show interest in offshore wind power development. Taiwan's abundant offshore wind power potential, avoiding protest from local people near the wind farms, have been the narratives used to promote OSW. After the Fukushima incident in Japan caused the Taiwanese government to adjust the energy policy to fully promote RE, OSW became one of the important sources for RE. Under the energy transition policy, the narratives have been further directed to the abundant OSW resource as Taiwan's "green gold," the job opportunities that OSW industry can bring, and the vision of Taiwan's leading position in OSW in the Asia-Pacific region and entrance into the global supply chain of OSW. Besides, because the air pollution problem has become serious in Taiwan, the government has also been using the narrative that replacing fossil fuels with OSW can lessen the pollution.

On the other hand, where the government has proactively promoted RE also seems to be where the biggest opposition to RE in Taiwan's energy history is. Negative narratives were propagated and discussed, especially from the pro-nuclear power coalition. These narratives mainly assert the volatility of RE, deem the geographical conditions of Taiwan (lots of typhoons) unsuitable for wind turbine, question the durability of wind turbines, point out that too high price-setting of FIT becomes the citizens' burden while the money ultimately flows into foreign investors' pockets, and promote the pathway of "use nuclear power to nurture green energy" to replace the current radical RE policy.

BOE and IDB of MOEA are the governmental departments involved most in promoting OSW (Table 3-7). More governmental departments, such as the Fisheries Agency, engaged in OSW development. Local governments become important actors, especially in Changhwa County and Yunlin County, which own most of the potential good wind farms. Taiwan's OSW developing attracted lots of foreign investors to come to Taiwan, even more than what the government had expected. Besides the government, the OSW developers can be said to be the most important actors to lead OSW development. Three different types of developer—foreign, domestic-foreign alliance, and domestic developers—were rewarded the projects in the selection and auction phases, of which around 80% of the capacity has been allocated to foreign developers, including Ørsted, wpd, Yushan, NPI, CIP, and Macquarie (aligned with Swancor). Taiwanese developers include Swancor, Taipower, and CSC. The developers play the leading role in forming the supply chain of their OSW projects, searching for local suppliers, sharing their experience, introducing foreign suppliers to Taiwan, and connecting Taiwanese companies with experienced suppliers for knowledge sharing, cooperation, and technology transfer (Figure 3-8, Figure 3-9, Table 3-8). This shows OSW developers, especially foreign ones, are major actors in networking Taiwan with foreign, well-experienced pioneers in the OSW field.

Besides developers' work on networking, the government supported the setup of the Offshore Wind Power Components Localization Industry Alliance, also called the "Wind Team," led by CSC, and the Offshore Wind Power Maritime Engineering Alliance, also called the "Marine Team," led by CSBC. These networks help gather and connect the related companies to form the supply chain for OSW.

Table 3-7 Main actors in offshore wind power development

Category	Actor
Governmental department	MOEA (BOE, IDB), Environmental Protection Administration (EPA), Fisheries Agency, local governments
Government-funding organization, governmental research institute	ITRI, Metal Industries Research & Development Centre (MIRDC)
Developer	• Foreign: Ørsted, wpd, Yushan, NPI, CIP, Macquarie • Taiwanese: Swancor, Taipower, CSC
Turbine manufacturer	Gamesa, MHI Vestas
Wind farm construction, turbine components manufacturer	Century Iron and Steel Industrial Co. Ltd (CT), Sing Da Marine Structure Corporation (SDMS), Formosa Heavy Industries, CSBC Corporation, Woen Jinn Harbor Engineering, Chin Fong, Tianli (Red Blades Wintek), Swancor, Atech Composites, Yeong Guan, TECO, Fortune Electric, Delta, Sinotech, Star Energy
NGO, interest group, civil group	Fishermen's Associations, pro-nuclear power groups, environmental protection associations, GWEC, professionals/experts
Transmission and distribution system operator	Taipower

Source: summarized by the author based on the analysis.

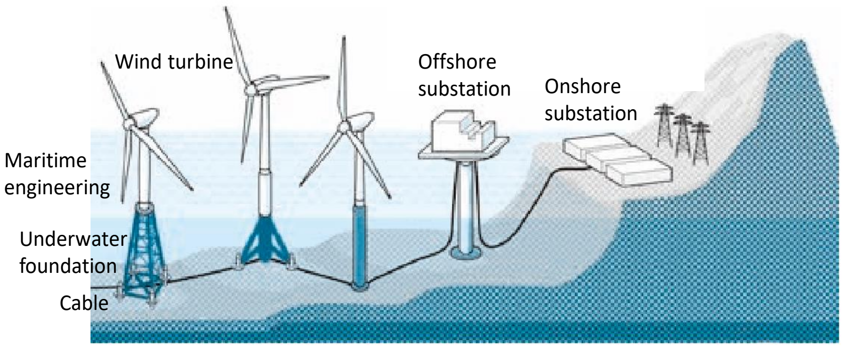

Figure 3-8 Composition of an OSW supply chain

Source: Image from K.-Y. Liu (2018), p. 119; edited by the author.

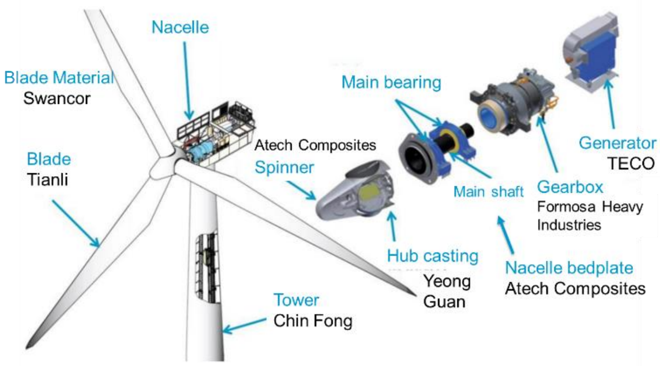

Figure 3-9 Main suppliers in the wind-turbine supply chain

Source: Image from OSHA (2019), p. 3; edited by the author.

Table 3-8 Main suppliers in the OSW supply chain

Segment		Taiwanese firm	Foreign firm
Underwater foundation		• Century Iron and Steel Industrial Co. Ltd (CT), Sing Da Marine Structure Corporation (SDMS), Formosa Heavy Industry • CTCI Machinery Corporation (CTCI MAC)	--
Maritime engineering		CSBC Corporation (+GeoSea), Woen Jinn Harbor Engineering, EGST	Jan DeNul N.V, Seaway Offshore Cables
Cable		Ta Ya	LS
Wind turbine		--	Gamesa, MHI Vestas
Turbine components manufacturer	Tower	Chin Fong	CS Wind
	Blade	Tianli (Red Blades Windtek)	--
	Blade material	Swancor	--
	Nacelle bedplate	Atech Composites	--
	Hub casting	Yeong Guan	--
	Spinner	Atech Composites	--
	Generator	TECO	--
	Gear box	Formosa Heavy Industries Corp.	--
Onshore substations	Components, system	Fortune Electric, Delta	--
	Construction	Sinotech, Star Energy	--
Operation and maintenance		Taiwan Offshore Wind Farm Services Corporation (TOWSC)	--

Source: summarized from IDB (2018) and news articles by the author; this data presents the situation as of January 2019.

3.4.3 Forming a protective space for wind power

The functions of the protective space in Taiwan's wind power development have been provided by the government and private sector within the primitive niche (Taiwan) and from the external niches as well. During the early years, Taipower tried to introduce wind power to the outlying Penghu Islands, providing the initial space for shielding. More concrete practices of shielding have included putting RE into the "Statute for Upgrading Industry" and announcing the "Wind Power Demonstration System Setting Subsidy" in 2000 to keep it away from competing with other energy options by using these general and specific regulations for financial support. Some Taiwanese firms which have invested in China started to work on wind power technologies due to China's passing of the Renewable Energy Law and proactively fostering wind power industry, which became a favorable environment for wind power technology development. Swancor, Red Blades Windtek, and Yeong Guan, which later become the important actors or suppliers in Taiwan's OSW development, belong to this category. Regarding OSW, subsidy to financially support OSW, i.e. the Offshore Wind Power Demonstration Incentive Program, was announced in 2015 to promote participation in OSW. Swancor, one of the OSW developers, was rewarded a demonstration project of 128 MW capacity, finally choosing to avoid controversial sites like the habitat of the Eastern Taiwan Strait population of Indo-Pacific humpback dolphins, a decision to operate OSW at the preferable place that reveals the shielding functional characteristics.

Demonstration projects are an important way to provide a learning opportunity in the nurturing function. Three onshore wind demonstration projects were executed respectively by the state-owned Taipower and the private companies Formosa Heavy Industries and Cheng Loong Corp., which were the first commercially operated wind-power projects in Taiwan. Germany wind-power developer InfraVest's entering Taiwan's wind power generation market did not only become one of forces to drive the diffusion of wind power, but also bring those opportunities for the governmental departments and the society to get to know about wind power. InfraVest was one of those who strongly promoted the FIT mechanism (J.-C. Hsu, 2006; K.-L. Huang, 2009; Kung & Lin, 2009). Those Taiwanese firms in China, such as Swancor, researched and developed wind power related technologies, and experienced contacting with the international major suppliers in wind power supply chain. They brought these achievements based on their "learning" in China back to Taiwan for OSW developing, expecting and trying to develop even more advanced technologies, like the Red Blades Windtek. The foreign developers of OSW brought their experiences, knowledge, networks, and partner suppliers to Taiwan, connecting these with the local Taiwanese companies for learning.

The development of onshore wind power in its initial stages depended greatly on the government's expectation of it to be a climate change countermeasure. Although the government also expected the diffusion will help establish the wind power industry and bring the business profits, the scale of the capacity allocated for installation each year was not large enough to foster the wind power industry (MacLaughlin & Scott, 2010). Moreover, the then growing wind power diffusion globally makes the wind turbine a "seller's market," which put Taiwan in a more inferior position in negotiation with the advanced international major suppliers (H.-L. Chen, 2007b). The early demonstration projects satisfied those participated firms in meeting their electricity needs economically while promoting their "green (environmentally friendly) image." InfraVest expected a chance for the wind power business in Taiwan. When turning to energy transition policy since 2016, the government expected OSW to be one of the main energies to replace nuclear power while also fostering OSW as a localized industry and bringing job opportunities, nurturing personnel, and making Taiwan the hub of OSW suppliers in the Asian region. The government largely propagated these visions and discourse to citizens, along with OSW developers and expected suppliers' support of it. Policy clarity and the determination to a large extent strengthen the expectation and confidence of investors in OSW.

Government-led network building was the main way for networking in onshore wind development, including supporting the setup of industry association and having governmental funding organizations like the ITRI work on searching local companies and help them interchange and connect with foreign companies. Regarding OSW, W-Team, and M-Team were set up to form the networks for suppliers. The leading firm CSC also helped foreign developers, like Ørsted, to visit promising local companies to form the OSW supply chain in Taiwan. Foreign developers work on networking foreign technologies and experience with Taiwanese firms. All these present an expanded and stronger network forming which include the active participation from foreign investors rather than how onshore wind power development was previously.

In the initial stage, the introduction of wind power was due to economic reasons. It cost more in purchasing fuels (due to the transport) in the outlying islands, and hence wind power generation was considered. Wind power was promoted earlier than solar PV because it performed better economically than solar PV did. These showed the fit-and-conform empowerment of wind power. In promoting OSW, the business chance that can be brought and the connection with local firms to be the suppliers are also evidence for OSW's practicality in the current environment. Furthermore, in the auction phase, the bidding prices are very close to the current average cost of power generation in Taiwan, showing that OSW is a promising energy source which can be economically competitive to other energy sources.

Both onshore and offshore wind power show their stretch-and-transform empowerment. InfraVest pressured the government by retreating investment from Taiwan and accusing the government of holding an anti-renewables stance, which finally pushed the government to pass the FIT mechanism (K.-L. Huang, 2009; InfraVest, 2009; Kung & Lin, 2009; S.-Y. Liu, Huang, & Lin, 2009). After 2016, the government's energy transition policy claimed that energy transition is a must-do for Taiwan and is a feasible policy. The government amended the Electricity Act to deregulate the electricity market, making it favorable for RE. When the FIT rate of OSW was questioned as too expensive, the government and developers claimed this is due to the goal of localizing the supply chain in Taiwan, legitimating the expense on OSW installation. The industry nurturing and the demand in (RE) electricity due to its sustainability to replace the nuclear power has supported OSW to be strong enough in the narratives and formulated institutions that favor itself as well.

3.5 Analysis

3.5.1 How the protective space has been formed

First, we observed that a government-led development, then business power, and network expansion and public participation subsequently emerged as the dynamics to form the protective space for RE in Taiwan. The government initialized the RE development, which later brought firms to participate in the business, and finally public participation which supports different business models and embraces different ideas, such as sustainability and local participation and benefits, to promote RE. This expansion and deepening of the network in turn has facilitated the diffusion of RE, making it easier than it was during the initial phase of RE introduction in Taiwan.

RE technologies are new for latecomer countries, and they have been introduced into these countries due to energy needs or for sustainable development. Hence, a government-led incentive calls for a mission-based development of RE to meet the policy needs and national planning. Commercial participation was boosted due to the government's policies in manufacturing or diffusion of RE. As in the case of Taiwan, InfraVest was attracted to Taiwan after realizing the then-government's anti-nuclear power stance, bringing its experience in Germany to invest in onshore wind power (J.-C. Hsu, 2006; K.-L. Huang, 2009; Y.-C. Liu, 2009). The major solar PV company Motech, one of whose founders went back to Taiwan from the US with his overseas experience and knowledge in solar energy, started the first PV company in Taiwan (Ge, 2017). Motech's move was even earlier than the government's support of the setup of PV companies. Some of the companies are spin-offs of the ITRI or have accepted technology transfer from it. These processes built Taiwan's capability in RE technology, including the physical technology, and soft aspects such as institutions and laws like FIT, and the impact resulted from RE introduction and diffusion, both positive and negative effects like the "Yuanli Anti-crazy Wind Turbine" (T.-L. Lin, 2015), which is an important process to get society to know and learn about RE.

Furthermore, different ideas of RE and various business models have gradually emerged under the global influence of sustainability value, climate change, and effects that resulted from RE manufacturing and diffusion in Taiwan, and brought by the electricity market reform which deregulates the market in favor of RE under the government's energy transition policy. We can see various actors start participating in RE's diffusion business, such as social entrepreneurs and cooperatives calling for public participation in solar power generation (like Sunnyfounder, Green Advocates Energy Cooperative); and some former PV manufacturers have changed their business to promote small-scale PV diffusion (like Sinogreenergy). These changes reveal that a protective space initiated by the government has gradually expanded to other actors, which help further RE diffusion.

The other prominent characteristic observed is that the domestic (Taiwan) niche has also leveraged the external (foreign) niches to provide the functions that a protective space should have when the domestic niche has failed to provide a fertile environment for developing RE. The developing of physical RE technology or the commercial experience can be transnational, across the border, proceeding in another (geographical) niche. This can be generally categorized into three patterns.

First, the external niche provides a space for shielding, meaning that RE technology develops in an external place that is in favor of it, rather than in an unfriendly environment. Furthermore, RE technology strengthens its technological or institutional capabilities, or even networking, in this external niche. After it becomes strong enough or its primitive (domestic) niche turns to offer a favorable condition for RE, it "swims back" to its "hometown" (the primitive niche), with its nurtured capabilities to help the formation of the niche in the hometown and even upgrade its RE technology. We can see this in the cases of Swancor which developed its technology in China then returned to Taiwan not only with technological capability but with further aims to become an offshore wind power developer. Red Blades Windtek also developed wind power technology in China and returned to Taiwan to be the local supplier of blades for MHI Vestas in Taiwan's OSW. New Green Power Co. provides a case of external learning of RE business operation by leveraging the rapid growth of PV installation in Japan after its introduction of FIT.

Second, the external niche can also provide similar nurture function for (Taiwan's) local companies that remain in the primitive niche (Taiwan). The obvious evidence is the development of Taiwan's PV industry which has benefited much from overseas growing PV markets such as Germany and Japan for exporting solar cells.

Third, technology transfer from advanced countries (a mature niche) to the local market, which is also a common pattern among latecomer countries. This simply presents the local niche's leverage of the mature technology and experience provided by the external niche (foreign investors). Belonging to this category are Taiwan's PV manufacturers' use of turnkey technology, the government's use of international cooperation programs in onshore wind, and the recent OSW development in which foreign developers' commitment to local content has been emphasized.

3.5.2 How the characteristics of the protective space affected RE diffusion

The development of the two RE technologies, PV and wind power, unfolded quite differently in Taiwan. This attributes largely to how they have been defined by the government during Taiwan's initial stage of RE promotion. In the initial policy guidance, the government considers RE promotion in an economic, cost-benefit way, looking at the RE technologies with a spectrum based on their maturity and commercial performance of technologies, while also taking Taiwan's industrial capability and the synergy between RE technology and other industries into consideration. This defines the different developing roadmaps for RE technologies, and the government's expectations, plans, and policies for RE promotion, which hence brought about the different development of PV and wind power. In short, wind power is a more mature and economic technology that should be diffused first while solar energy was still in its R&D phase and its R&D efforts may have synergy with Taiwan's semiconductor industry. Therefore, wind power has largely been promoted since around 2005, while solar PV obtained more R&D budget from the government than wind power did.

Although originally the government also intended to promote the RE industry through its deployment, the nurturing of the wind power industry failed to catch up with the wind power installation. More accurately, the installed capacity for each year was not large enough to successfully establish a local industry supply chain (MacLaughlin & Scott, 2010), nor was it wisely leveraged in tenders to attract foreign major turbine manufacturers to trade for technology transfer (H.-L. Chen, 2007c). Besides, the then "seller's market" situation in global wind power technology market put Taiwan in an even more difficult position (H.-L. Chen, 2007a, 2007b). This resulted in that all the turbines deployed were imported, with only a few local contents employed. Expectation, network expansion, and learning, which are expected to be brought in the nurture function of niche, were not satisfactorily operated, resulting in failure in establishing a successful niche supported by local people. However, during this process, foreign investment brought awareness of RE to the Taiwanese people and learning in the institutional aspect such as FIT. Due to the impact and protest from wind power, discussions on proposals such as promoting public participation in RE diffusion, setup of public RE generators or energy companies to be operated by local people, had been brought up (ITRI, 2015), although not successfully realized in the end.

The "failure" in onshore wind power became a lesson for the following (current) offshore wind developments. Taiwan benefits from good wind speeds on its west coast, the Taiwan Strait, where there are top offshore wind farms that have been reported by some foreign institutes (Li, 2018; Zhang, Zhang, Chang, Liu, & Zhang, 2017). The government proactively wanted to utilize this resource to make up for the power insufficiency due to nuclear power phase-out. OSW accordingly has been largely leveraged to attract foreign investment while the government also set strategy to ask for a local supply chain commitment from the foreign investors. Job opportunities and a promising vision of becoming a global supplier in the future have been propagated by the government in order to strengthen the niche. This continuing story of offshore wind power development in Taiwan unfolded as a contrary to the onshore wind power development in the past.

On the contrary, the PV industry has been encouraged in R&D and was regarded as an expensive source for power generation, and hence was not promoted largely in diffusion. Even after the introduction of FIT, the government soon adopted auction scheme to cool down the rush into PV installation and avoid "burning money." A "slow then fast" strategy was taken in PV diffusion. However, business opportunity emerged in solar PV products due to the diffusion expansion in Germany and other countries, and Taiwanese manufactures leveraged this chance to export PV products overseas. Taiwan's PV industry hence almost relied on overseas market, leading to the abnormal development of the supply chain—mainly focused on the middle stream, especially on cell manufacturing. Due to lack of domestic market for diffusion, there was less incentive for the manufacturers to invest in the downstream of the supply chain, such as the PV system equipment. This then became the fragility of the PV industry when competing in the global market, especially with China, because PV firms do well if they own a vertical, integrated supply chain in-house. However, the situation has been gradually changing after the energy transition policy announced, which supports the full promotion of domestic PV diffusion, i.e. a total of 20 GW installation by 2025. This has brought a good opportunity for PV manufacturers to shift from solar cell manufacturing to the downstream system segment and even to investment in power generation, and also encouraged mergers among PV firms. Besides, civil participation in PV has emerged, which has brought a variety of business models in PV installation.

The formation of Taiwan's RE niche, to a considerable extent, leveraged external niches. Beyond the abovementioned policy reason to cause this, this can also be attributed to globalization and Taiwan's limited domestic market and dependence on international trade.

The PV industry relied on the foreign market to prosper, although afterwards they have been suffering from keen international competition, especially from China. This lessened the niche's pressure to sell PV products in the domestic market, constituting an unfavorable environment for PV diffusion. Meanwhile, some firms leverage the external niche to learn about PV diffusion. For example, New Green Power Co.'s participated in the PV operation business in Japan, and then brought their experience back to Taiwan (C.-F. Wu, 2017), standing as one of the top PV developers (S. Chen, 2019).

Regarding wind power, the niche development that leveraged external niches can be roughly categorized into three forms. First, external niches provide their "achievements" of RE development, including physical technology, knowledge and experience and related institutions to the primitive Taiwan niche. Firms such as CSC, Formosa Heavy Industries, received technology transfer through the industrial cooperation programs supervised by IDB. This deployment of wind power showed the Taiwanese people about wind power technology, which also brought anti-wind turbine protests. Institutions that favored RE, such as FIT, were propagated by the foreign wind power developer. These present the learning of the soft, institutional aspect regarding the technology, along with the physical technology itself. This is common to see especially in latecomer countries when accepting technology transfer from advanced countries.

Second, the external niches provided the space for the primitive niche to practice the shield and nurture functions. Companies located in China nurtured their technological capabilities. Furthermore, for either the Taiwanese firms in China that participated in the boom of the Chinese wind power market, or those Taiwanese firms that stayed in the primitive niche (i.e. Taiwan) facing a domestic market without certain installed capacity nor an friendly environment, both of them had to face the pioneering Western wind power technology suppliers directly. This pressured them to improve the technology or to know what criteria will be required of international, world-class suppliers.

Third, all these external or internal developed firms' capability and experience are combined, with the leading foreign OSW developers bringing international networks and experience into Taiwan and incorporating the Taiwanese industrial basis to lead the OSW development under the government's planning.

The analyses in this section can explain why the diffusion of RE started from wind power then to solar PV, and also shed light on the "failure" in coordinating manufacturing and diffusion in onshore wind and solar PV. It also reveals that relying on the external niche can bring positive and negative effects. The external, foreign niche can provide a temporary space for the primitive niche to nurture the potential and strengthen itself, while a vigorous external niche can also be such a haven for the primitive niche so that it ends up failing to grow to maturity or grow soundly to fulfill RE diffusion in its old (original) place.

3.6 Conclusion

In this chapter, by adopting Smith and Raven (2012)'s elaboration on the functional properties of a protective space (niche), we investigated the development of Taiwan's solar PV and wind power development to uncover how a niche for RE has been formed and developed in an RE latecomer country. We obtained the following two main findings.

First, we observed that the RE niche in the case of Taiwan has been formed through the functioning of inner and outside shielding and nurturing. This reveals that foreign niches can make up for those functions that the domestic niche failed to provide. This may happen when a domestic niche is ill-functioned due to the innate or acquired unsound environment. By saying "innate" we refer to resource endowment. This is shown in Taiwan's constraint market for onshore wind power deployment, compared to countries like China and India that can more easily attract foreign investors and trade domestic market for technology transfer and investment to nurture their RE industry. Regarding the "acquired" environment, we mainly pointed to those policy measures, determinations to develop RE, technological capability, and others.

This observation hence responded to the discussion of the geographical limitations in the current concept of niche or protected space. We presented how the outside protective space can also involve the niche functions and suggest a possible strategic leverage from the domestic niche when facing an unsound environment. However, geographical factor can bring both positive and negative effects to the shielding, nurturing, and empowering functions during the formation of the local (domestic) niche technology. This is because the fertile foreign niche may conversely become a paradise for the local niche, which weakens the pressure that the local niche is supposed to bring to the regime.

Second, the abovementioned pattern of niche formation has a lot to do with the government and its policy guidance. Although policy always plays an important role in RE promotion, for a latecomer country which takes the government-led way of promoting RE, how the government leads the direction will impact the level of technology penetration and the industry nurturing, which later affects its energy transition. Moreover, the government-led way also posts a different picture from what is suggested in SNM literature, i.e. a bottom-up development of niche.

Chapter 4
Unfolding the Energy Transition: The Nuclear Power Phase-out Decision-Making Process in Taiwan

4.1 Introduction

In Chapter 3, we investigated how the RE niche in Taiwan has been formed and matured the RE technologies. In this Chapter, we further want to understand how the niche RE technology has contested with other (mainstream) technologies; and during this process, how these three levels of MLP (namely niche-innovations, socio-technical regimes, and socio-technical landscapes) have interacted; and how the endogenous dynamics have affected the unfolding of energy transition (Y.-c. Chen, 2018b).

As we mentioned in previous chapters, energy transition relates to the transformation of the current energy system we have been deeply embedded in, which makes it a “wicked problem” (Geels & Schot, 2010; Holtz et al., 2015; Moallemi & Malekpour, 2018; Verbong & Loorbach, 2012). A multi-level perspective (MLP) which emphasizes the alignment of three levels (niche-innovations, socio-technical [ST] regimes and socio-technical landscapes) in transition studies has provided a framework for working on such system innovation.

However, MLP has been criticized for lack of political accountability and “agency” (Geels, 2011; Lockwood, Kuzemko, Mitchell, & Hoggett, 2013). It remains unpredictable when the transition will happen and how fast it will be (Verbong & Loorbach, 2012). It also cannot explain why there are better and poorer performers among those countries that have been working on energy transition (Lockwood et al., 2013). Moreover, while the Fukushima disaster can be identified as landscape shaking in MLP, it has profoundly different effects across different countries (Hindmarsh & Priestley, 2016), such as Japan, Germany and Taiwan. This shows the importance of investigating local contexts, besides checking on the alignment of the three levels, to understand the dynamics that drive or delay energy transition, while also echoes to what Geels and Schot (2010) indicates regarding applying MLP: “specific patterns and speed depend on local event sequences and conjunctures.”

Under its energy transition policy, Taiwan announced nuclear power phase-out and an increase in RE up to 20% of electricity generation by 2025, which made it the first country in Asia to enforce a nuclear power phase-out policy after the Fukushima Daiichi nuclear disaster in Japan (Suzuki, 2017). In this chapter we conduct a longitudinal investigation into Taiwan’s nuclear power phase-out decision-making process through the MLP lens, aiming to explore how these three levels, i.e. niche-innovations, socio-technical regimes and socio-technical landscapes, have interacted and how the endogenous dynamics (mainly including political, economic, and civil) within them have affected and catalyzed the decision to phase out nuclear power. In doing this, the conditions that facilitate or delay energy transition and their endogenous dynamics will thereby be revealed.

4.2 Methods

4.2.1 Analytical framework

This chapter takes MLP, the most renowned theory in transition studies as well as the basis for other approaches (Moallemi et al., 2017; Wieczorek, 2018), as the main research framework. In order to investigate what the concrete conditions and endogenous dynamics required to facilitate transition, and to shed light on agency during this process, we begin by considering the three major actors in the energy sector: policymakers, the energy industry (incumbent utilities, new entrants, energy related firms), and energy users (consumers, industrial and commercial firms, civil society) (Lockwood, 2015). Given this, we can conclude political, economic and civil dynamics are essential components that shape energy transition. Furthermore, we investigate the phase-out of nuclear power in Taiwan which intends to use RE to make up for the power generation. With the indication that development of nuclear power would exhaust the resources and support necessary for RE's realization of learning economy (Lockwood et al., 2013), we hence will focus specifically on the interaction between nuclear power and RE. The various advocates and vested interests involved in nuclear power or RE are then grouped as the nuclear coalition, the anti-nuclear coalition, and the RE coalition respectively, to represent the actors and their influence.

4.2.2 Methodology

This research used a qualitative methodology which included a literature review and documentation data compilation and analysis. Statistical data, chronological timelines and events as empirical evidence were used to help conduct a longitudinal analysis of Taiwan's energy policies and transition development. The data and literature review can be separated into two parts. One forms the theoretical basis of the research, including sustainable transition studies and renewable policy related research from academic journals, working papers, and books. The other consists of the Taiwan case study materials, which include: 1) primary data and policies on electricity and renewables, mainly collected from the websites and publications of the Ministry of Economic Affairs, the Executive Yuan, the Legislative Yuan, Taiwan Power Company (Taipower), Industrial Technology Research Institute (ITRI), and Taiwanese newspapers (such as Apple Daily, China Times, Liberty Times, United Daily News); and 2) secondary data compiled from research reports and articles provided by think tanks and research institutes (such as Chung-Hua Institution for Economic Research), academic journals, and news magazines (such as CommonWealth Magazine).

Mainly referring to Mori (2018, 2019), and also to Geels et al. (2016) and Verbong and Geels (2007), to begin with, we describe Taiwan's energy transition pathway landscapes by presenting the energy policies characterizing each period of development. Then, the roles of the political, economic, and civil dynamics, and development of coalitions (nuclear, anti-nuclear and RE) will be analyzed, to reveal the endogenous dynamics at work and their impact upon transition. Finally, we will discuss how these case study results can contribute to current work on energy transition studies employing MLP.

4.3 Landscapes and the energy transition pathway

Landscape plays an important role in shaking the regime, which can then give chance to niche technology to replace the incumbent prevailing technology. Landscapes can be grouped into three types (Geels, 2002, 2004a, 2004b; Geels & Schot, 2010; Van Driel & Schot, 2005): a) the material context of society, such as the material and spatial arrangements of cities, electricity infrastructures; b) slow-changing factors, such as economic growth, broad political coalitions or changes in political culture and ideologies, environmental problems, climate change;

and c) shocks and surprise, such as rapidly rising oil prices.

Four landscapes in the Taiwan case can hence be identified, as the following.

1) Oil crises and political liberalization (1945–1980s)

The ST regime of Taiwan's power sector had been formed with the electricity system which has a vertically integrated, state-owned monopoly Taipower, under the authoritarian ruling of Kuomintang (KMT; Chinese Nationalist Party) after World War II, as the infrastructure to support economic, industrial development and the KMT government. Electricity generation shifted from relying on hydro power then to thermal power in the mid-1960s (Taipower, 2017). The oil crises in the 1970s urged the KMT government to work on the diversification of energy supply, considering proactively employing nuclear power which had been under construction and developing RE (H.-P. Chen, 2015a; Chiang, 2008; Taipower, 2017).

In the 1970s, KMT's ruling legitimacy was getting questioned because of losing the membership in the UN and ending official relations with the US. In order to maintain its ruling, KMT opened more political opportunities for local Taiwanese people (Shen, 2001; Yeh, 2012), including more seats for elections. The political liberalization let the "dissidents," civil society emerge, bringing different voices to oppose to the incumbent ST regime (Ho, 2001; Shen, 2001; Yeh, 2012).

2) Trends of economic liberalization and political democratization (late 1980s–1990s)

Following the lifting of the Taiwan Martial Law in 1987, Taiwan moved toward democracy. Democratic Progressive Party (DPP) became the main political representative for those "dissident voices," including anti-nuclear issue (Ho, 2016). The emerging environmental awareness of Taiwanese people made it more difficult for Taipower to build new power plants, and also under economic liberalization trend in the world, KMT hence adjusted the regime by opening partial of the electricity generation market (CEPD, 2013; J.-Y. Hsu, Chao, Tsao, & Huang, 1995; Taipower, 2016, 2017).

3) Climate change and party alternations (1998–2010)

In response to the Kyoto Protocol, the first National Energy Conference was held in 1998 and concluded with an increase in RE use (BOE, 2007; H.-P. Chen, 2015a). In 2000, Taiwan has the first political party alternation in its history: DPP in power. This revealed party alternation becomes part of the political culture and system, as it does in other democracies. Different perspectives and policies can thus be brought into the regime along with different political parties in power, and hence a radical adjustment, or even replacement, of the regime will become possible. In 2008, KMT got back in power again, until 2016 when DPP gained the presidency.

4) The aftermath of Fukushima Daiichi nuclear disaster (2011 till now)

The Fukushima disaster impacted on energy policies in many countries, including Taiwan. Civil anti-nuclear protests also resurged after the Fukushima to pressure the ruling KMT (Ho, 2018). DPP, in power again since 2016, announced energy transition policy and nuclear power phase-out by 2025.

4.4 Political, economic, and civil dynamics during the energy transition pathway

1) Oil crises and political liberalization (1945–1980s) (Figure 4-1)

Oil crises caused the KMT government to adjust policy, which promoted nuclear power largely (Taipower, 2016, 2017), and hence nuclear power soon became an important component of the ST regime, to support the infrastructure and economic development (see **Figure 4-1** for “nuclear” [without the circle] showing its emerging into the regime [“nuclear” with the circle]). During 1978–1985, three nuclear power plants were constructed consisting of six reactors, and the fourth one (FNPP) was under planning (Taipower, 2016, 2017). A nuclear power favored regime accordingly formed, supported by the nuclear coalition which mainly consisted of KMT, Taipower and its related firms, nuclear researchers, industries and business firms.

However, some “dissident scientists” who has obtained information about Three Mile Island accident happened in the US, started to question the regime’s advocacy of nuclear power, initiating the anti-nuclear power argument in Taiwan (Ho, 2001, 2016). The anti-nuclear coalition was thus gradually formed, mainly by anti-nuclear power scientists, people in medical, media, cultural communities, residents near the site of FNPP, and political dissidents against KMT (Ho, 2001). Facing the anti-nuclear power argument and the slowing down of electricity consumption, KMT government announced to suspend the FNPP plan in 1985 (China Times, N.D.; Taipower, 2016; UDN, 2014).

The government also began to research wind and solar power but did not promote much (see **Figure 4-1** for “RE: solar, wind” [without the circle] to represent its emergence but in a small scale [“RE” with the circle]) (H.-P. Chen, 2015a). Hence, RE developed as a niche research auxiliary to the regime. RE coalition also emerged, but was small, mainly in the governmental research institutes and universities, such as ITRI and National Tsing Hua University (H.-P. Chen, 2015a; Chiang, 2008; Hwang et al., 2008).

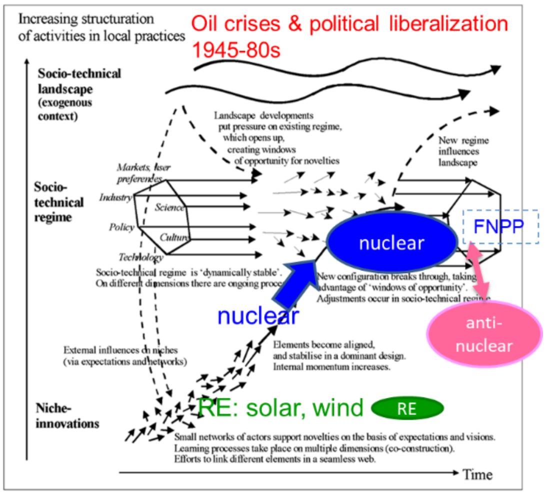

Figure 4-1 MLP on Taiwan’s energy transition: oil crises and political liberalization (1945–1980s)

Source: background figure is adopted from Geels and Schot (2010); edited by the author.

Notes: (1) The circles here, namely “RE”, “nuclear”, and “anti-nuclear,” represent each coalition (their advocates, interest groups) respectively. The different sizes of these circles represent their development, power (such as “how they are supported by government”), and contestation with the others, etc., during different periods (landscapes) according to the storylines and analysis in this chapter; (2) The background figure here only helps show the position of each coalition and the contestations between them under the MLP framework. It does not mean an occurrence of transition at this point. The same as in the other similar figures (periods) in this chapter; and (3) Regarding “nuclear,” the share of nuclear power in Taiwan’s electricity generation during different periods has also been taken into consideration when drawing its circles in different figures: nuclear power grew during 1978–86, maintained around the same share during 1987–2014, and decreased since around 2014.

2) Trends of economic liberalization and political democratization (late 1980s–1990s) (**Figure 4-2**)

DPP formally became the political representative of the anti-nuclear coalition in the parliament (Ho, 2002), to challenge the nuclear-favored regime led by KMT. However, the opposition DPP could not stop KMT from passing the FNPP budget and starting to construct FNPP. The nuclear coalition successfully supported the stability of the regime.

KMT government liberalized partial electricity generation market to independent power producers (IPPs) in 1995 (Taipower, 2016, 2017), generating thermal power, which was an adjustment of the regime in order to keep it stable. However, it turned out that there was an IPP also opposing to the FNPP (Ho, 2016), showing that IPPs could be a part of the regime, while also shaking the regime for pursuing their own interests (profits from thermal power generation).

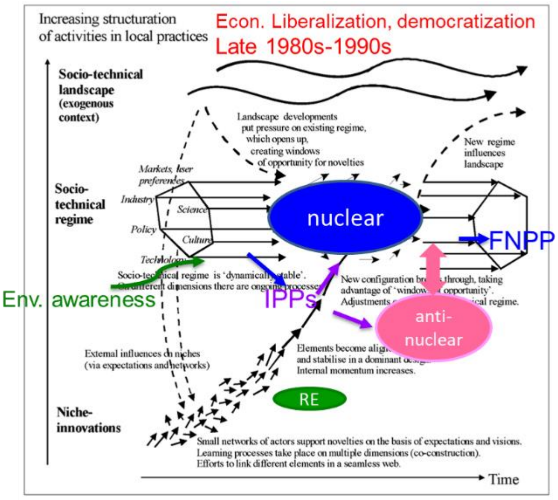

Figure 4-2 MLP on Taiwan's energy transition: economic liberalization and democratization (late 1980s–1990s)

Source: Geels and Schot (2010); edited by the author.

3) Climate change and party alternations (1998–2010) (**Figure 4-3**)

Climate change urged the regime to offer RE a more legitimate stake in the power sector, opening the reward-demonstration period of RE since 2000 and diffusion period since 2009 under the passing of Feed-in Tariff (FIT) scheme (**Figure 4-4**). Meanwhile, countermeasures to climate change also stabilized nuclear power in the regime due to its zero emission (H.-P. Chen, 2015a; Tseng, 2015).

DPP in power since 2000 brought the nuclear-free country concept into the regime, later legalized in the Basic Environment Act (2002). Nevertheless, the failure to stop the construction of FNPP, due to the regime resistance including opposition KMT, frustrated the anti-nuclear power movement, which then stopped the annual anti-nuclear power demonstration until the Fukushima accident (**Figure 4-5**) (Ho, 2016). KMT returned to the administration in 2008 and specified nuclear power as the option to reduce CO_2, further strengthening the pro-nuclear power regime (Tseng, 2015) (see **Figure 4-6** for different stances on nuclear power between the KMT and DPP administrations).

PV and wind power industries began to grow and export overseas after 2000, under the global RE needs (**Figure 4-7**, **Figure 4-8**) (H. Chu & Lan, 2009; Kang et al., 2012; Kang et al., 2017). Taiwan's solar cell manufacturing ranked 2nd in the world since 2010. RE firms hence gradually became a strong member in the RE coalition. This shows RE was no longer an R&D technology in the niche, but should be taken more seriously by the regime. This drove the KMT government to implement green energy industry fostering projects in 2009 and 2014, along with the global trend of the "Green New Deal" (MOEA, 2009).

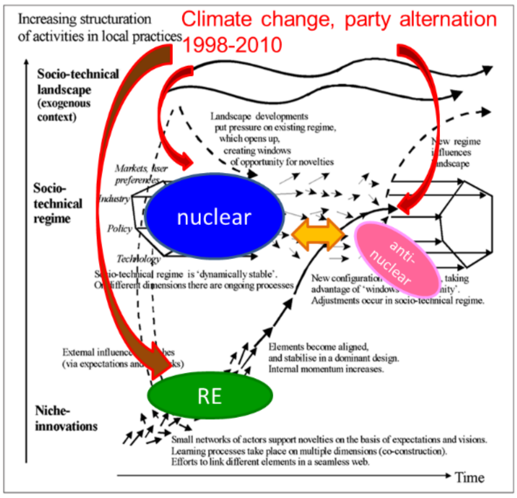

Figure 4-3 MLP on Taiwan's energy transition: climate change, party alternation (1998–2010)

Source: Geels and Schot (2010); edited by the author.

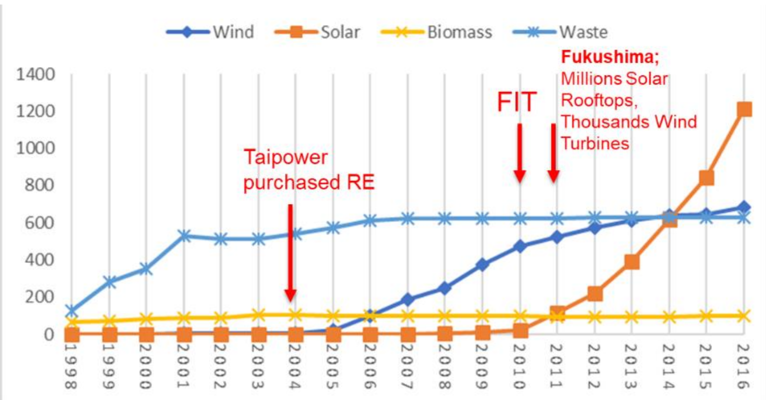

Figure 4-4 Renewable energy cumulative capacity in Taiwan

(Unit: MW) Source: BOE (2017); chart made by the author.

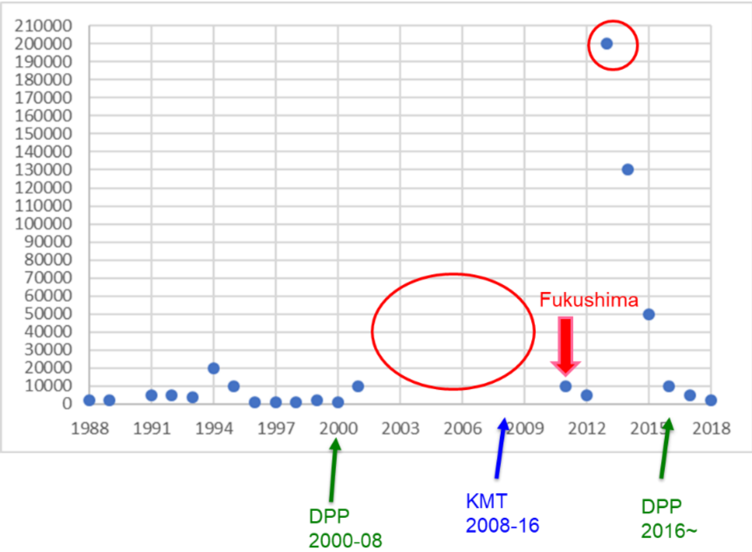

Figure 4-5 Numbers of protestor in the main anti-nuclear power/anti-FNPP demonstrations (1988–2018)

(Unit: number of persons)

Notes: 1) Only show the numbers of protestor in the main demonstration for each year; 2) Some of the numbers are subject to the author's bias in selecting the data due to the different numbers reported according to different news sources.

Sources: referred to Ho (2016)'s analysis; data collected from Ho (2016) and news databases (Apple Daily, China Times, Liberty Times, UDN); charted by the author.

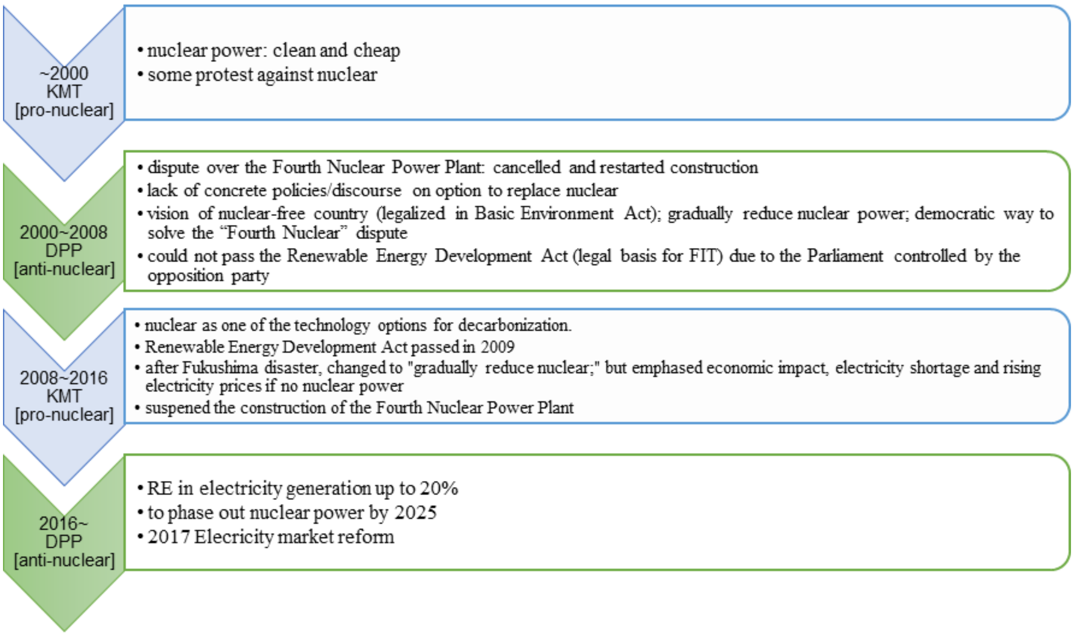

Figure 4-6 Nuclear policies and its intertwining with RE during different administrations in Taiwan

Sources: adopted from Y.-c. Chen (2018a); summarized from Tseng (2015) and others.

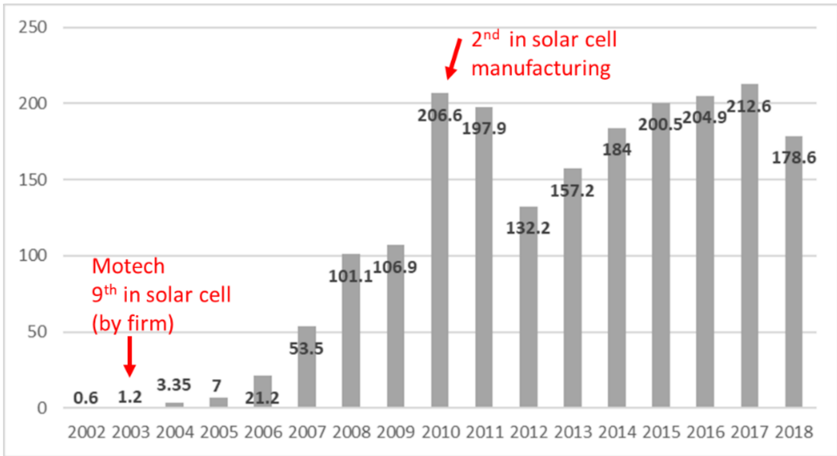

Figure 4-7 Total production value of the PV industry

(Unit: Billions of New Taiwan Dollars [NTD])

Sources: data collected from C.-S. Chen (2008) and IDB (2019) (data provided by ITRI); adopted from Figure 3-2, edited by the author.

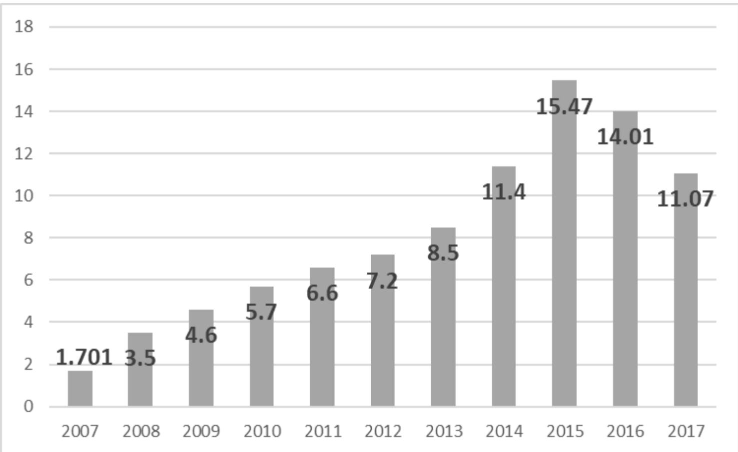

Figure 4-8 Total production value of the wind power industry

(Unit: Billions of NTD)

Sources: data collected from W.-W. Lin (2009), The Epoch Times (2007), and Emerging Energy Industry Yearbooks (2011-2018) published by ITRI; charted by the author.

4) The aftermath of Fukushima Daiichi nuclear disaster (2011 till now) (**Figure 4-9**, **Figure 4-10**)

The Fukushima disaster compelled the KMT to adjust its energy policy, which included gradual reduction of nuclear power, no extension of the current nuclear reactors in operation, ensuring the safety of FNPP before starting operation, and fully promotion RE with the "Million Rooftop PVs" and "Thousand Wind Turbines" promotion projects (OOTP, 2011). However, it still intended to maintain the pro-nuclear power regime.

On the other hand, civil dynamics emerged to support the anti-nuclear power protests (**Figure 4-5**). The anti-nuclear coalition included over one-hundred various of NGOs and organizations, celebrities, artists and even NGO led by politically pro-KMT persons (Ho, 2016, 2018). The grassroots anti-nuclear movement, with even hunger strike protest, finally pushed KMT to adjust the regime again, suspending the FNPP construction in 2014, when the administration's legitimacy was weakened politically by the Sunflower Student Movement[12] and the split inside the KMT regarding the FNPP issue (Ho, 2016).

DPP returned to power in 2016 and announced energy transition policy, which included amending the Electricity Act to legalize nuclear power phase-out, to liberalize the electricity market with green energy to go first, and to restructure Taipower (Y.-c. Chen, 2018a; EY, 2017; MOEA, 2016). DPP also tried to use civil society, such as the "Open Taipower" research team, to weaken Taipower and the regime (Hao, 2016; C. Lin, 2016). Through promoting RE, especially offshore wind power, DPP intended to expand the RE coalition and wear down the pro-nuclear power regime, so as to pull RE out of the niche, and finally into the regime to replace nuclear power.

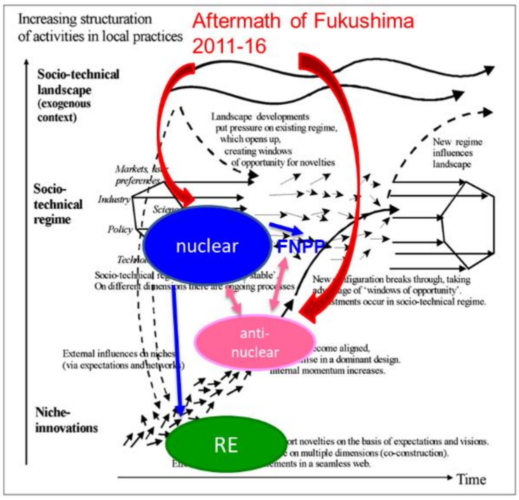

Figure 4-9 MLP on Taiwan's energy transition: aftermath of Fukushima (2011-2016)

Source: Geels and Schot (2010); edited by the author.

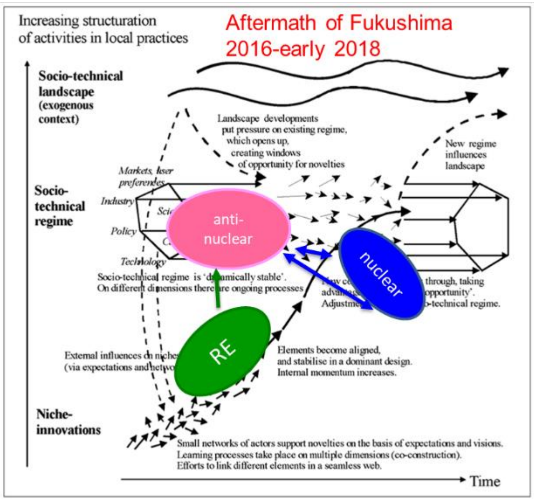

Figure 4-10 MLP on Taiwan's energy transition: aftermath of Fukushima (2016-early2018)

Source: Geels and Schot (2010); edited by the author.

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12 A protest movement led by students and civil groups objected to the passing of the Cross-Strait Service Trade Agreement (a trade pact with China).

4.5 Discussion

4.5.1 The timing and conditions fostering the energy transition

The above analysis reveals that successive landscape-shaking with the support from endogenous dynamics may help facilitate sustainable energy transition (**Figure 4-11**). Party alternation in 2000 let DPP bring the anti-nuclear concept into the regime, although the regime strongly resisted, and it ended up frustrating the anti-nuclear movement. "Nuclear-free country" since then became a concept hidden in the regime. After the Fukushima, KMT adjusted nuclear policy as no extension of current nuclear power reactors (originally scheduled to phase out by 2025 if no extension), but still faced strong civil anti-nuclear protests. This accompanied the then weak, unstable ruling KMT political power, bringing KMT's suspending FNPP. This accordingly made DPP, in power since 2016, easier to enforce nuclear phase-out policy, which was under the situation different from its first time in power (2000).

Booming RE industries in the 2000s made the government pay more attention to the influence from niche technologies, and implement FIT mechanism and green energy industry promotion projects, which in turn expanded the RE coalition. DPP announced nuclear phase-out and propagated the economic benefits that RE such as offshore wind power will bring, in order to use economic and civil dynamics to confront the resistance from the regime.

These show that under landscape-shaking, endogenous response to support the moves toward transition is needed. Maybe the transition will not be induced at once, but the accumulation of these kinds of efforts may facilitate transition to come about. Therefore, policy makers need to make good use of these dynamics and capture the opportunities to accelerate energy transition.

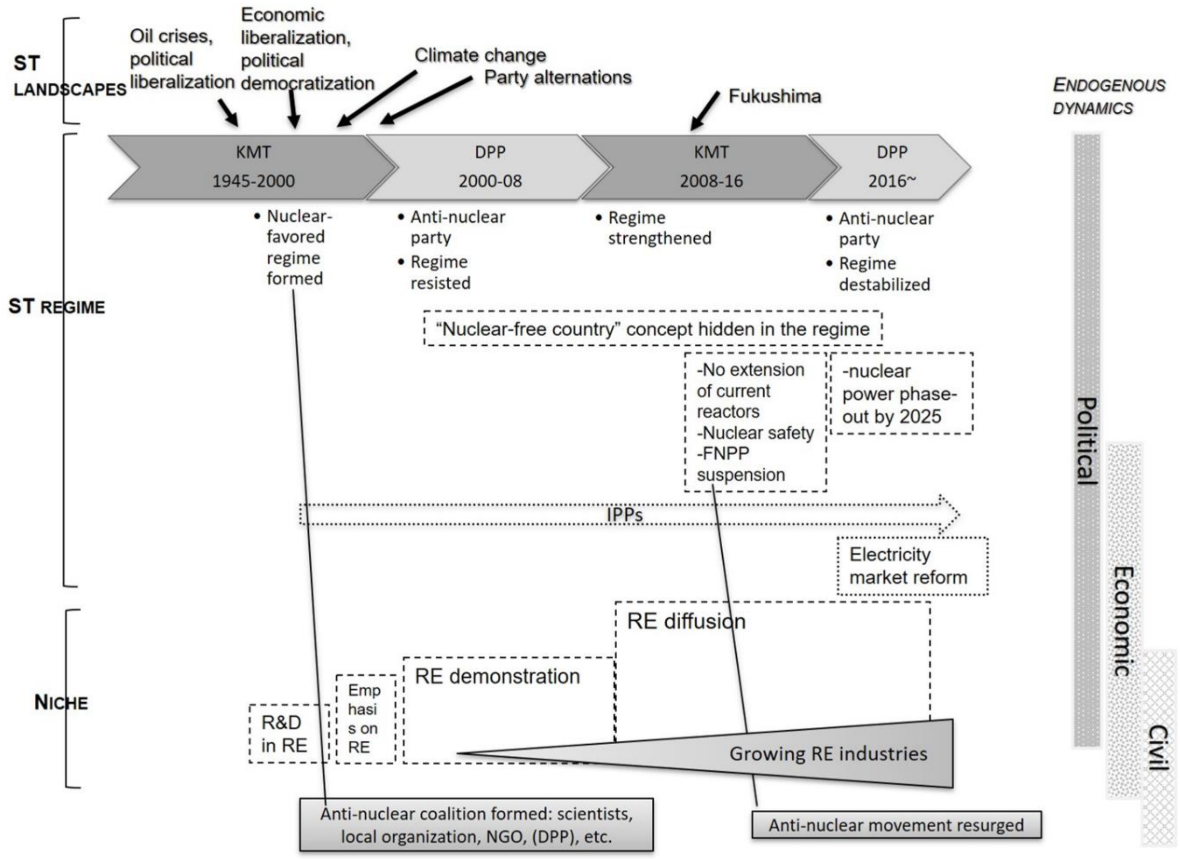

Figure 4-11 MLP on Taiwan's energy transition

Source: charted by the author based on the analysis.

4.5.2 Endogenous dynamics under landscape pressures

By examining energy coalitions (nuclear, anti-nuclear, and RE) and observing the political, economic and civil dynamics within them, several implications are obtained for applying MLP to energy transition studies. First of all, political dynamics may form and strengthen the incumbent regime, like KMT and the pro-nuclear regime; or shake the regime, like DPP's anti-nuclear stance, trying to promote RE and liberalizing electricity market. However, insufficient political power may lead the incumbent regime to a more stable one (like DPP's resuming FNPP in 2001) or an unstable one (like KMT's suspending FNPP in 2014).

Furthermore, energy policy is a field of economic policy (Pegels & Lütkenhorst, 2014), which is even the case in a country which had taken a developmental-state path economically, such as Taiwan (Chou, 2017; W.-W. Chu, 2011; J.-H. Wang, 2010). This reveals how deeply economic dynamics can impact energy transition. Nuclear-power favored regime had been formed to support economic development and KMT's political legitimacy. The government's support for the export of RE products rather than domestic diffusion also demonstrated the effort of economic dynamics. In addition, while regime adjusts itself to maintain the stability as responding to the discoordination inside the regime or to the landscape shaking, it may also drive actors to step into opposite coalitions, which in turn challenges the regime. For example, actors in the nuclear coalition (e.g. semiconductor firms, firms in the supply chain for Taipower) stepped into the RE coalition under the booming RE industry; IPPs' speaking out against FNPP for their economic interests in power generation.

Finally, civil dynamics can play a key role in helping shake the regime. The anti-nuclear power movement was initiated by dissent scientists which formed the anti-nuclear coalition to challenge the regime. Although the anti-nuclear power movement was initially combined with political dynamics (i.e. DPP), after the Fukushima accident, the anti-nuclear protests went a bipartisan way and gained even larger support (Ho, 2016, 2018), and hence forced the regime need to adjust again (FNPP suspension), which then facilitate the energy transition. However, one single landscape may not induce such strong public sentiment. This also resulted from the long-time dominance of the regime which brought discoordination between the regime and civil society, such as citizens' contradictory sentiments toward the state-owned monopoly Taipower (e.g. accepting their discourse of nuclear power and RE, while also doubting nuclear-power safety and Taipower's management efficiency).

4.6 Conclusion

In this chapter, we applied MLP as the theoretical framework to analyze the nuclear power phase-out decision-making process in Taiwan, aiming to explore how niches, regimes and landscapes have interacted and how the endogenous dynamics (political, economic, and civil) within them have affected and catalyzed the decision to phase out nuclear power, in order to understand the conditions that could facilitate or delay energy transition. The results show that successive landscape-shaking along with support from endogenous dynamics may help facilitate energy transition.

Chapter 5 Discussion

Through investigating the case of Taiwan, this dissertation explores how an RE latecomer country with an industrial basis can move towards energy transition. I applied the MLP in transition studies to help explain the energy transition process.

5.1 Forming the niche

I started with the question of how the niche has been formed. By investigating wind power and PV development in Taiwan in Chapter 3, we found that besides using the local niche, Taiwan also leveraged external (foreign) niches to make up for what its niche environment could not provide. Such a "strategy" might not have been a deliberate choice, but instead, was driven by commercial dynamics. In the end, however, it functioned as a protective space outside of Taiwan. This points out geographical limitations in the concept of niche, addressing the "spatial narrowness" issue as mentioned in some previous transition studies in developing countries (Wieczorek, 2018). However, unlike some latecomers for which the niche technology formed completely externally, or which rely heavily on foreign actors, what has been shown in Taiwan is that the international flow of the local (Taiwanese) actors to the external niche help complement the functions that a sound niche should have provided. This finding implies that for latecomers that do not have a friendly niche environment, well-functioning niche, nor large-sized market to bargain over obtaining advanced RE technology, this way of leveraging the external niches could be an option for forming the protective space for RE development.

5.2 Aggregating the dynamics for energy transition

This kind of niche formation involves international factors that do not necessarily play the role of facilitating energy transition at once although they have helped mature the niche. As Taiwan's PV development has relied on foreign markets and was promoted by the government, it did not present as the absolute power to pressure PV's diffusion domestically nor did it trigger the sustainable energy transition. One important reason is that most of the PV products have been shipped overseas for trading, so the RE technology and its coalition can survive and develop by relying on the foreign niches, which avoided it from causing the inner incoordination to shake the regime.

The Taiwan case shows contestation between RE and nuclear power. It was not until the political party with the anti-nuclear power stance in power that the (notable) window of opportunity was created for RE, such as onshore wind power since 2000, and offshore wind power and PV since 2016. However, diffusion of RE did not succeed on the first try. It shows that during the early 2000s, the niche for wind power was still in its process of maturing whether utilizing the Taiwan domestic niche or the foreign one, and also due to the insufficient supporting measures and other factors, it turned out not leading to a large scale diffusion or a well balance between RE consumption and production.

Finally, successive landscapes aggregated with political, economics, and civil dynamics helped shake the nuclear power favored regime, which facilitated the anti-nuclear coalition, especially the anti-nuclear ruling party to execute the energy transition policy, opening the windows of opportunity for RE to emerge. Such emerging of RE then feeds back to itself, further developing (such as OSW) or maturing (such as the PV supply chain) the niche to make it stronger towards energy transition.

5.3 Towards the energy transition

Based on the answers to the sub-research questions, we turn back to the main research question: how can an RE latecomer country with an industrial basis move towards energy transition?

An RE latecomer may leverage the protective space at home and abroad to mature the niche, especially when the local environment is not friendly enough for niche development. As suggested in the previous research, transition is a slow and long-term process, but what we want to emphasize here is the cumulation in this process. During each shock in the landscape, there shows some room for the niche developing and brings discoordination inside the regime, which gradually accumulate as the dynamics to facilitate energy transition.

The expectation of leapfrogging in the latecomers may sometimes be illustrated as leapfrog in environmental technology, to put it more accurately, as fostering eco-industries that can compete with the advanced ones, especially in industry-based countries, but such types of policies or expectation do not ensure domestic diffusion of RE or triggering of the energy transition, not to speak of its original intention as environmental leapfrogging to avoid environmental convergence. However, such industry fostering can be the basis or dynamics for the energy transition to come. Under the aggregated dynamics in favor of transition, the policymaker can direct the way towards energy transition, which then feedbacks to further mature the niche that enforces the moving towards a sustainable energy system. Leveraging the timing thus proves more than important for policymakers.

Moreover, this dissertation provides two important implications. One is how the RE latecomer country can shift from the thought of leapfrogging as catching up in RE technology toward a true environmental leapfrogging (i.e., transforming to a sustainable energy system). During the development of RE in latecomer countries, business is also taken into consideration. However, contrary to what is argued in EMT, i.e., advanced environmental policy pioneers in environmental technologies, the introduction of RE in latecomers under the pressure of tackling climate change may present difficulties in successfully integrating R&D, manufacturing, and the diffusion of RE. This may result from insufficient technological and industrial capability, economic consideration, and the government's policy guidance, which constitute the issues for the full diffusion of RE and energy transition.

In the case of Taiwan, the consideration of economic efficiency can be said to be the most important factor. Wind power was promoted to diffuse earlier because of its maturity, whereas solar PV gained more R&D budget because of its potential for development and synergy effect with Taiwan's semiconductor industry. In addition, the promotion measures were not strategically planned, thereby resulting in the failure in nurturing the supply chain to sustain wind power deployment. Conversely, solar PV industry has been supported by private firms, the government, and then the global trend of Green New Deal, which led to Taiwan's solar cell manufacturing being the second largest in the world. Nevertheless, soon faced with fluctuation in global market, price drop in upstream materials, and intense competition with China's manufacturers, the solar PV industry has ironically become the "miserable industry" in Taiwan. While owning the second largest share in solar cell manufacturing, the low diffusion rate of solar PV in Taiwan also presents as an odd phenomenon. This is discussed in Chapter 4: even if the technological capabilities have been established, the aggregating of the endogenous dynamics and the successive landscape-shaking that brought about the lack of coordination of the regime are required to help facilitate the unfolding of energy transition. Namely, it is not leapfrogging development; instead, the accumulation of these forces with the timing to be leveraged leads the move towards transition. The immature niche and misalignment of the three levels resulted in diffusion being faster than production or more production than diffusion, neither of which can cause a real energy transition.[13]

Furthermore, this highlights the second implication of this dissertation. Sustainable energy transition involves a transformation of the whole energy system. It needs not only the policy but also economic and social aspects to sustain the transition. This is the reason that the formation of the niche and the maturity of the RE technology are so important. However, RE, such as solar and wind power, come from natural resources, whose development are, to a certain extent, subject to the endowment of each country. Particularly with regard to wind power, as shown by the cases of China and India, their large markets can be leveraged for technology transfer from foreign advanced countries or to help nurture global champion turbine manufacturers (Y.-c. Chen, 2016). In addition, in the case of Japan, the capital and brand name can be used to support the cooperation with main global players to gain a share in the global wind power market, such as MHI's cooperation with Vestas in OSW to form the MHI Vestas. Nevertheless, when no such advantage exists, the question arises of how a small- or middle-sized market latecomer country can sustain its wind power deployment through assuring that profit can trickle down to local people, namely, gaining the balance between manufacturing and diffusion. The case of Taiwan's wind power shows the initial development failed in acquiring such a balance. The formation of its niche and technological accumulation partially come from the government's supporting projects during this period. Lacking a large-scale domestic market to sustain its development, Taiwan's local firms were required to meet the global advanced criteria to export their products overseas. Additionally, some firms by chance could leverage the external niches to nurture their technologies. These firms are now gathering to be led by the foreign OSW developers under the government's support for foreign investment and technological localization, which accordingly strengthen the niche. This implies that when a local niche is unable to provide a sound environment, a strategic utilization and the mobility of the elements that constitute the niche may be beneficial directions for future efforts. However, in the end, it still depends on the determination of the policymakers to open the windows of opportunity, as argued by Geels and Schot (2010): "Even when structural alignments raise the probability of transitions, actors may or may not take advantage of windows of opportunity."

[13] This analysis was also inspired by the argument in EMT as well as Akihisa Mori's comments on the integration of energy policy and industry-fostering policy to trigger energy transition.

Chapter 6 Conclusion

By investigating the case of Taiwan, this dissertation answered the following question: how can an RE latecomer country with an industrial basis move towards sustainable energy transition? This question was addressed because insufficient technological capabilities, economic concerns, and other factors may make it even more challenging for an RE latecomer to pursue a sustainable energy system, although they have been expected to have the possibilities of passing an environmental leapfrogging development pathway. Arguments such as specific policy measures to promote RE deployment, learning curve for RE technology or innovation system cannot solve the issue of pursuing a sustainable energy system, which requires the coevolution of both the production side and also the consumption side. This highlights the importance of our research question here. The answer to this question can provide policy implications for those emerging and future generations of newly industrialized countries that are tackling the governing of a sustainable energy transition. The case of Taiwan was chosen as the study case for several reasons. First, Taiwan demonstrates an industrial basis for RE manufacturing. Second, Taiwan has already developed and promoted RE diffusion for around twenty years but encountered a gap between RE production and consumption. Third, the Taiwanese government is actively promoting energy transition policy at present.

To address this main research question, I applied the multi-level perspective (MLP) from transition studies as the fundamental theoretical basis for this dissertation. From a perspective of a long-term historical observation, I compiled numerical and qualitative facts from news, governmental documents, and other sources to formulate the storylines in order to conduct a longitudinal analysis of the RE history. This was then combined with the MLP and the elaboration on niches to answer two sub-research questions. To begin with, I answered the first sub-research question: how has the RE niche in Taiwan been formed and matured the RE technologies to provide the basis for energy transition? By adopting the elaborated definition of a niche as a “protective space,” I investigated the development of solar PV and wind power in Taiwan. I subsequently found that apart from the domestic niche, RE development in Taiwan also leveraged the external niche to function as a place for shielding and nurturing. However, relying on external niches might also hinder the domestic niche from maturing.

Subsequently, by analyzing the nuclear power phase-out decision-making process, I answered the second sub-research question: how has the niche RE technology contested with other (mainstream) technologies; and during this process, how have these three levels (namely niche-innovations, socio-technical regimes, and socio-technical landscapes) interacted; and how have the endogenous dynamics affected the unfolding of energy transition? The results show that successive landscape-shaking with support from endogenous dynamics may help facilitate energy transition.

Based on the results of the identified two sub-research questions, I confirmed that the main research question of this dissertation was answered. The results show that for a latecomer country with an industrial basis to move towards energy transition, it may leverage domestic and foreign niches to accumulate its capability and help mature the local niche. Regarding the unfolding of the energy transition, the aggregation of political, economic, and social dynamics in favor of a sustainable energy transition with the leverage of policymakers in terms of the timing may open windows of opportunity for a sustainable energy transition.

Three contributions of this dissertation are thus specified. First, through the application of the MLP as the theoretical framework, this dissertation complements the discussion on the level of niche to solve the "technology inherent" presumption and geographical constraint issue in MLP. The result particularly contributes to the RE latecomers. Second, by analyzing the unfolding of the energy transition, this research identified three groups of actors, namely policymakers, the energy industry (incumbent utilities, new entrants, energy related firms), and energy users (consumers, industrial and commercial firms, civil society), and extended them as presenting the endogenous dynamics (namely political, economic, and social dynamics) that drive energy transition, which addressed the "lack of agency" criticism of MLP. Third, by investigating the Taiwan case, we have presented an ongoing sustainable energy transition in an RE latecomer, which can specifically provide implications for those small- and middle-sized latecomer countries that have little leverage against the global landscape. This is also the most important social contribution of this dissertation.

Case studies provide an effective method to study transition issues because they allow for the tracing of abundant contexts and developments that enables us to research the processes of transitions. This dissertation reviews and formulates the storylines of RE development and sustainable energy transition in Taiwan. This dissertation further applies MLP and the argument of niche in this case study, and presents the academic contributions of this research and the implications of a transition pathway for small- and middle-sized countries. However, the political, social, and economic landscapes are different in each country. As Geels and Schot (2010) stated, "specific patterns and speed depend on local event sequences and conjunctures." This research adopted MLP as the global theory to investigate the case of Taiwan and observed the pattern of the niche formation and the endogenous dynamics and aggregating processes for unfolding the energy transition. Nevertheless, to convert it into a broader explanation or generalize for transition theory, a further exploration into other similar cases is needed.

Hence, for future research, one direction is to study those countries that are under similar conditions to Taiwan, regarding their industrial basis and small- and middle-sized markets. This would help us examine and generalize the findings and move from case studies to a typological theory. Another research direction would be to examine the differences among RE technologies. For example, Taiwan presented different development pathways for wind power and solar PV. The environment and technological as well as industrial capabilities needed for specific RE technology are thus considered to be different and hence may play a vital factor in niche formation and energy transition.[14] This is an important topic for the future.

[14] This idea was also partially inspired by Soete (1985)'s argument regarding technological leapfrogging for newly industrializing countries.

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Appendix I: Taiwan's renewable energy policies

Targets for RE development in Taiwan

Date	Policy/Law	Contents
2008-6-5	Sustainable Energy Policy Guideline	**8% RE** in power generation until 2025.
2009-6-12	Renewable Energy Development Act	To reward RE installation capacity up to **6.5GW-10GW** totally. [Art. 6] (Feed-in Tariff introduced; first rate announced in 2010)
2010-10-20	RE promotion target	Total RE installation capacity up to **10,858MW** by 2030
2011-11-3	New Energy Policy	To fully support RE; Total RE installation capacity up to **12,502MW** by 2030
2014-1-13	RE target	Total RE installation capacity up to **13,750MW** by 2030
2015-7	--	Total RE installation capacity up to **17,250MW** by 2030
2016-5-25	New Energy Policy	RE in electricity generation target raised to **20%**; Phase-out of nuclear power by 2025.
2016-6-22	Green Energy Policy Target (report at LY)	RE in electricity generation up to 20%; total RE installation capacity up to **27,423MW**.
2017-1-26	Electricity Act amendments	Electricity market for RE will be liberalized by July 2019; phase-out of nuclear power by 2025.
2017-5-16	Energy transition roadmap	Power generated from RE: up to 9% by 2020, 20% by 2025. Composition of electricity generation in 2025: RE 20%, gas 50%, coal 30%.

(Source: adopted from Y.-c. Chen (2018a))

Appendix II: Wind power development in Taiwan

List of onshore wind farms in Taiwan (as of January 2019)

No.	Owner	Name of wind farm	Numbers of turbine	Capacity of turbine (kw)	Capacity of installation (kw)	Turbine manufacturer	Year of operation
1	Miaoli	竹南	3	2000	6,000	Enercon	2006
2	Miaoli	竹南	1	1800	1,800	Enercon	2006
3	Miaoli	大鵬	21	2000	42,000	Enercon	2006
4	鹿威風力	Changbin I	21	2300	48,300	Enercon	2007,2010
5	鹿威風力	鹿港 1 期	11	2300	25,300	Enercon	2008
6	鹿威風力	彰濱鹿港 2 期	8	2300	18,400	Enercon	2010,2011
7	中威風力	大甲大安 1 期	13	2300	29,900	Enercon	2009,2012
8	中威風力	大甲大安 2 期	8	2300	18,400	Enercon	2009
9	中威風力	大甲大安 3 期	3	2300	6,900	Enercon	2012
10	中威風力	大豐	8	2300	18,400	Enercon	2012,2013
11	中威風力	台中市	1	2300	2,300	Enercon	2012
12	中威風力	大豐 2 期	1	2300	2,300	Enercon	2015
13	中威風力	臺中市大甲區	1	2300	2,300	Enercon	2016
14	觀威風力	Guanyin	15	2300	34,500	Enercon	2009,2010,2012
15	觀威風力	Taoyuan Guanyin	2	2300	4,600	Enercon	2013
16	觀威風力	Guanyin II	2	2300	4,600	Enercon	2012
17	崎威風力	竹南 2 期	3	2300	6,900	Enercon	2011
18	桃威風力	新屋	2	2300	4,600	Enercon	2011
19	豐威風力	Xinfong	5	2300	11,500	Enercon	2012
20	龍威風力	HoulongI	13	2300	29,900	Enercon	2013
21	龍威風力	HoulongI	1	900	900	Enercon	2013
22	龍威風力	Houlong II	1	2300	2,300	Enercon	2013
23	龍威風力	Houlong II	1	900	900	Enercon	2013
24	龍威風力	Houlong III	2	2300	4,600	Enercon	2016
25	龍威風力	Houlong IV	1	2300	2,300	Enercon	2016
26	龍威風力	Houlong IV	1	900	900	Enercon	2016
27	龍威風力	Houlong Wind Power	1	2300	2,300	Enercon	2016
28	通威風力	Tongyuan I	6	2300	13,800	Enercon	2014
29	通威風力	Tongyuan II	3	2300	6,900	Enercon	2014

No.	Owner	Name of wind farm	Numbers of turbine	Capacity of turbine (kw)	Capacity of installation (kw)	Turbine manufacturer	Year of operation
30	通威風力	Tongyuan Fanglibei	1	2300	2,300	Enercon	2014
31	通威風力	Miaoli Tongxiao	2	2300	4,600	Enercon	2016
32	通威風力	台中市大安區	1	2300	2,300	Enercon	2018
33	清風風力	台中市清水區	1	2300	2,300	Enercon	2016
34	東鋼風力	龍港風力電廠	5	2300	11,500	Enercon	2016
35	禾風	雲林縣麥寮台西鄉	1	2300	2,300	Enercon	2018
36	安威風力	台中市大安區西部	2	2300	4,600	Enercon	2017
37	安威風力	台中市大安區	1	2300	2,300	Enercon	2016
38	安威風力	台中市大甲區	1	2300	2,300	Enercon	2016
39	安威風力	台中市清水區	1	2300	2,300	Enercon	2018
40	台朔重工	麥寮一期	4	660	2,640	Vestas	2000/12
41	天隆造紙	竹北春風	1	1,750	1,750	Vestas	2002/10
42	Taipower	澎湖中屯一期	4	600	2400	Enercon	2001/10
43	Taipower	澎湖中屯二期	4	600	2400	Enercon	2005
44	Taipower	核一廠風場	6	660	3,960	Vestas	2005/1
45	Taipower	桃園大潭	3	1 ,500	4,500	GE	2005/6
46	Taipower	桃園大園觀音	20	1 ,500	30,000	GE	2006/5
47	Taipower	香山風力	6	2,000	12,000	Gamesa	2007,2008
48	Taipower	台中港區風力	18	2,000	36,000	Zephyros	2007,2008
49	Taipower	台中電廠風力	3	2,000	6,000	Zephyros	2007/4
50	Taipower	核三廠風場	3	1 ,500	4,500	GE	2005/5
51	Taipower	台電彰濱一期	23	2,000	46,000	Vestas	2007/4
52	Taipower	雲林麥寮一期	15	2,000	30,000	Vestas	2009/1
53	Taipower	四湖風力	14	2,000	28,000	Vestas	2010/10
54	Taipower	林口風力	3	2,000	6,000	Vestas	2011/3
55	Taipower	台電彰濱二期	8	2,000	16,000	Vestas	2010/12
56	Taipower	雲林麥寮二期	8	2,000	16,000	Vestas	2010/5
57	Taipower	彰化王功風力	10	2,300	23,000	Enercon	2011/3
58	Taipower	大潭二期	3	2,000	6000	Vestas	2011/7
59	Taipower	大潭二期	2	2300	4600	Enercon	2011/7
60	Taipower	金門金沙風力	2	2,000	4,000	Vestas	2010/7
61	Taipower	澎湖湖西風力	6	900	5,400	Enercon	2010/12

No.	Owner	Name of wind farm	Numbers of turbine	Capacity of turbine (kw)	Capacity of installation (kw)	Turbine manufacturer	Year of operation
62	Taipower	桃 園 蘆 竹 Luzhu	8	900	7,200	Enercon	2015/6
	Total		**349**		**688,950**		

Sources: compiled by the author from "Thousand Wind Turbines Project" platform – GIS (http://pro.twtpo.org.tw/); also referred to the information from MOEA and Taipower.