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Carbon continuity

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Carbon Continuity:
Explaining the Changing Energy Mix of Taiwan’s Power System after the Second World War

DISSERTATION

to obtain the degree of Doctor at Maastricht University,
on the authority of the Rector Magnificus, Prof. dr. Pamela Habibović

in accordance with the decision of the Board of Deans,
to be defended in public on Thursday 27 June, 2024, at 10:00 hours

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CONTENTS

LIST OF ABBREVIATIONS

Abbreviation	Definition
AC	Alternative Current
AEC	Atom Energy Research Committee, now known as the Atomic Energy Council
CIE	Chinese Institute of Engineers
CIECD	Council for International Economic Cooperation and Development
CPC	Chinese Petroleum Corporation
CUSA	Council for United States Aid
CWB	Central Weather Bureau
DC	Direct Current
DEF	Danske Elvae Kers Forening
DOR	Department of Reconstruction
DPP	Democratic Progressive Party
EIA	Environmental Impact Assessment
EPA	Environmental Protection Administration
EPZ	Export Processing Zone
ESB	Economic Stabilization Board
FHIC	Formosa Heavy Industries Corp.
GEL	Gibsin Engineer, Ltd.
GW	Gigawatts
IAEA	International Atomic Energy Agency
IDC	Industrial Development Council
IPP	Individual Power Producer
ITRI	Industrial Technology Research Institute
JCSD	Joint Committee of Coal and Coke Supply and Distribution

JGW	J. G. White Engineering Company
KAIST	Korea Advanced Institute of Science and Technology
KASC	Kaohsiung Ammonium Sulfate Corporation
KHB	Kaohsiung Harbor Bureau
KMT	Kuomintang, the Nationalist Party
KOPEC	Korean Power Engineering Company
KV	Kilovolt
KW	Kilowatts
LDPE	Low-Density Polyethylene
LNG	Liquefied Natural Gas
LTS	Large Technical System
MLP	Multi-Level Perspective
MMO	Marine Mammal Observers
MOEA	Ministry Of Economic Affairs
MW	Megawatts
NEAT	New Energy Association of Taiwan
NRC	National Resource Commission
OWE	Offshore Wind Energy
OWF	Offshore Wind Farm
PCAC	Provincial Coal Adjustment Committee
PCCC	Provincial Coal Control Commission
PECL	Pacific Engineers & Consultors, Ltd.
PPA	Power Procurement Agreement
PRC	People's Republic of China
ROC	Republic of China

STS	Science, Technology, and Society Studies
TCC	Taiwan Co-Generation Corporation
TEPU	Taiwan Environmental Protection Union
TFC	Taiwan Fertilizer Corporation
TMMC	Taiwan Machine Manufacturing Corporation
TPB	Taiwan Production Board
TPC	Taipower Company
TRA	Taiwan Rail Administration
TSMC	Taiwan Semiconductor Manufacturing Company
TVA	Tennessee Valley Authority
UIRI	Union Industrial Research Institute
WTG	Wind Turbine Generator

GLOSSARY OF POWER INDUSTRY TERMS

Technical term	**Explanation**
Baseload power	The portion of the generator's load that remains constant.
Blackout	Sudden disruption of electrical power.
Brown out	An intentional or unintentional drop in voltage in the utility mains power supply. Intentional brownouts are used for load reduction in an emergency. The reduction may last minutes or hours, as opposed to short-term voltage sag (or dip) lasting seconds caused by other factors.
Combined Heat and Power	A generating set (or multiple sets) is used to utilize the heat produced (via the exhaust and the radiator) and produce electricity.
Distribution	Supply lower voltage electric power from a centralized substation to the point of end-use.
Distributed system	Systems that are installed at or near the location where the electricity is used, as opposed to central systems that supply electricity to grids.
Frequency	The number of cycles of an alternating current in a given time, i.e., Hz per second.

KV transmission lines	Transmit kilo-voltage electricity from the generation source or substation to another substation in the electric distribution system.
Load balancing	A common term used to describe the best practice of balancing the load evenly across 3 phases where possible. Regarding the Negative Phase Sequence entry below, it must be noted that for 3-phase generators, the load must be balanced within the negative phase sequence rating of the generator; otherwise, the generator can be overheated.
Load factor	The ratio of average load to the generating set power rating.
Nuclear reactor	A device in which a nuclear fission chain reaction occurs under controlled conditions so that the heat yield can be harnessed or the neutron beams utilized. All commercial reactors are thermal reactors, using a moderator to slow down the neutrons.
Overload	A term refers to the amount by which an electrical circuit exceeds its rating.
Off-peak	A specific period is when the power demand of a system is comparatively low.
Pump-storage system	It is a hydroelectric energy storage type involving two water reservoirs situated at different elevations. When there is surplus power on the grid and low electricity demand, the excess power is utilized to pump water from the lower reservoir to the upper one using reversible turbines. Later, when the electricity demand is high, the water is released downhill into the lower reservoir, which drives the turbines in the opposite direction to generate electricity.
Turbine generator	A turbine generator generates electricity through electromagnetic forces caused by steam, water, wind, etc.
Voltage drop	The loss of voltage between the input to a device and the output from a device due to the internal impedance or resistance of the device.

Acknowledgements

By the time I write this page, I have already moved back to Taiwan, an island country that just took a severe hit from the earthquake in April 2024. Taiwan has always been my research focus for its resilience against various threats, be it natural disasters, domestic political turmoil, or hostile external influences. Delving into its energy pasts offers me a different angle to have a deeper understanding of such capacity. In a sense, I was also learning how to be resilient during my PhD. The journey was arduous. I stumbled a lot, but I am glad I chose to start this journey in Maastricht.

Writing my dissertation at Maastricht University allowed me to distance myself from my possible biases and broadened my horizons by learning from many insightful thinkers. My two supervisors, Cyrus Mody and Vincent Lagendijk, are at the top of the list. I enjoyed exchanging ideas with them and always received more from their valuable feedback. They have been very supportive and constructive in guiding me through piles and piles of research materials and sharpening my way of thinking throughout my PhD years. I honestly cannot ask for more. Along the way, colleagues were also generous enough to offer their help and time to discuss my messy notes. To name a few, Geert Somsen, Lea Beiermann, Dani Shanley, Odinn Melsted, Manling Yang, Liang-Kai Yu, and Ci Tien. This dissertation was gradually in shape thanks to many of you, and the final touch was based on the valuable comments from my assessment committee, Anique Hommels, Wiebe Bijker, Hyungsub Choi, Brigitte Le Normand, and Wen-Ling Tu. I am very grateful to have such a wonderful team to be the first readers.

Lacking self-confidence and feeling uncertain about writing is the anxiety that I found particularly challenging. It is not always content-wise, but more like a reminder popping up at the end of every single chapter, asking, “Have I made myself clear? Does this help explain anything? What makes this argument different from others?” Therefore, I genuinely thank all the scholars and peers who found my studies interesting and some even willing to work together, especially Mila Davids, Eric Berkers, Honghong Tinn, Yu-fong Wang, Wen-ling Hong, and people in the Centre for Innovative Democracy. I also would like to express my gratitude to the financial support from the Ministry of Education, the EDF, the European Association of Taiwan Studies, and Ørsted for giving me the luxury to have—at least one thing— that I do not need to worry about.

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Chiayi, 1 May, 2024

Chapter 1: Past energy transitions in Taiwan

> When the United States broke the diplomatic ties with the Republic of China in 1979, the government not only encouraged but also instructed that coal should be bought from the United States to gain the sympathy and support of the American people for our country and to use the business practice as a bargaining chip for the government. At that time, Taipower had already explained to the government that U.S. coal was at least ten dollars more expensive than Australian coal per ton, and Taipower followed the instructions but unexpectedly took the blame... *Hui Huang, Chief Manager of Taipower Company (TPC) from 1950 to 1962.*[1]

The quote above refers to the Pan's Coal Purchase case of 1989, which caused Hui Huang's successor and the directors of the fuel department of Taiwan's state-owned utility, Taipower Company (TPC), to become involved in a twenty-year lawsuit. They were accused of improperly benefiting the commission agent, P&C Bituminous Coal Inc., based in Tennessee, by signing a contract with a higher purchasing price.[2] From the TPC's perspective, such a purchase was only possible under specific order from the government. Considering the urgent circumstances during the turbulent years of the oil crises and Taiwanese government's delicate diplomatic situation, TPC was thus, granted the permission to choose their preferred purchase contracts for fuels that would serve the best "national interests."

After a long debate, the court awarded no punishment at the end. Yet, this case exemplifies how Taiwan's past energy decisions were made within a complicated political and economic context. The geopolitical factor has always been in the minds of TPC system planners since the system's colonial past (originally founded as Taiwan Denryoku Kabushiki Kaisha in the Japanese ruling period) and rehabilitation in early post-war Taiwan. When considering the optimal energy mix of the power system, the TPC engineers not only calculate the seasonal water level changes, varied fuel costs, and loads by different time horizons to find cost-efficient practices, but also the political risks and opportunities behind its energy choices. Especially in critical moments, TPC engineers' agency plays a significant role in propping up the government – both in terms of its ties with the U.S. and the domestic fuel supply.

With hindsight, the decision to shift to imported fuel oil and coal in the late 1960s consolidated Taiwan's high energy dependency on imported fuels and its carbon-intensive

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[1] Rui-yong Zhu, "木瓜溪水力開發第一人: 朱書麟 [The First Person to Develop the Mugua River Hydraulic Power: Zhu Shu-lin]," *Yuan Magazine*, 2005, 60-70.

[2] Since TPC is a public utility, the case was charged in 1989 by Control Yuan, the central government's supervisory and auditory body, almost one decade after TPC signing the contract. The Control Yuan of Republic of China Gazette, (Taipei: The Control Yuan of Republic of China, 2009).

power system, bringing as many drawbacks as benefits in the following decades. However, the island country was not always this way. Hydropower and domestic coal used to dominate Taiwan's power generation and fueled industrial growth from its first electrification during Japanese colonial rule until the Nationalist government's shift to oil coinciding with the burgeoning petrochemical industry in the mid-1960s. This dissertation therefore asks: what turned Taiwan, once a self-reliant island power system largely dependent on renewable (hydropower) energy, into a hydrocarbon-based system with a high dependency on imported energy? As many studies of energy transitions would agree, the mix of different energy carriers in an electricity system is a technical question – but also often a social and political question with, in Taiwan's case, significant consequences both for the organization of the island's society and its relations with other states.

This question, not only relevant for Taiwan, has attracted scholars' attention since the concept of sustainability was coined in the late 1980s, especially once the contribution of carbon dioxide emissions to climate change became widely understood.[3] Yet, the visions and mechanisms of energy decision-making varied. As the sustainability transition studies literature has shown, resilient pathways to the future can only be understood by looking at each society's energy pasts.[4] By contextualizing the varied energy decisions over time, this dissertation elaborates how TPC system was built and shaped after the Second World War and became inextricably intertwined with Taiwan's carbon economy in the making.

Revisiting almost eighty years of development from the TPC system's reconstruction to the current renewable transition, this dissertation cannot cover all the historical events in between. Instead, I re-evaluate the key factors that contributed to the decision to change the power system's energy mix at several critical inflection points – before the Taiwanese government implemented its first energy policy in 1968; during the energy debates about oil and nuclear energy in the 1970s-1990s; and following the renewable (re)turn after the 2000s – with the TPC system's dependence on hydrocarbons growing from one chapter to the next. This general timeline of my study will help readers to grasp how plans for Taiwan's energy sources at any given time were vehicles for various interests (and why many of plans for the island's energy system ultimately failed to come about). The ebb and flow of those plans

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[3] The idea of sustainability could be traced to the 1969 when Buckminster Fuller popularized the concept of "Spaceship Earth" as a metaphor for the resource and energy self-sufficiency needed for the survival of humanity in his vision. See R. Buckminster Fuller, *Operating Manual for Spaceship Earth* (Southern Illinois University Press, 1969), 143. By the early 1970s, internationalists had taken up Fuller's claim of "planetary interdependence" and it used as the basis of a transnational governing system to tackle the environmental crisis, or more specifically, the cross-regional phenomenon of climate change. It provides the basis for developing strategies toward "sustainable development," which was established as the UN's overarching task in the *Our Common Future* report in l987. See Perrin Selcer, *The Postwar Origins of the Global Environment: How the United Nations Built Spaceship Earth* (Columbia University Press, 2018), 379.

[4] Laur Kanger and Johan Schot, "Deep transitions: Theorizing the long-term patterns of socio-technical change," *Environmental Innovation and Societal Transitions* 32 (2019): 7-21; Gregory C. Unruh and Javier Carrillo-Hermosilla, "Globalizing carbon lock-in," *Energy Policy* 34, no. 10 (2006): 1185-97.

constantly reshaped the conceptions of engineers, policymakers, and the public regarding energy extraction, conversion, and consumption, energy politics, and the environment in Taiwan. By presenting the contested views of various actors concerning Taiwan's energy choices in different socioeconomic and (geo)political contexts, I aim to offer a dynamic understanding of what triggered Taiwan's energy transitions over time and contributed to its significant dependency on imported fossil fuels, which by 2021 accounted for almost 80 percent of total power generation.[5] Furthermore, this dissertation attempts to explain the changing energy mix of the TPC system not in isolation but in co-evolution with its fuel storage facilities and transportation network, such as railways, ports, and pipelines, and with some of its largest users, such as the chemical industry. I argue that overlooking the systemic connections would lead to misunderstanding the triggers of the energy transition at different times.

The following chapters are arranged into three parts in response to three following sub-questions: (a) What energy futures did TPC engineers envision under the Nationalist state's economic rehabilitation plans that resulted in growing import dependency?, (b) How did TPC's carbon-intensive infrasystem react to the multiple crises in the 1970s and the following social democratization?, and (c) What does enlarging the capacity of renewable generated electricity entail for localities in Taiwan and for the existing nation-wide carbon-intensive network? As the story unfolds, it will become clear that the TPC system's evolution epitomizes an island’s changing economic landscape geographically, but always connected in terms of its energy sources to various continents. It is only possible to comprehend these system planners' decisions by placing them back into the specific circumstances of Taiwan's political and social context.

The historical arc of that context is that the island country went from being a proto-colonial space contested by the Dutch East India Company and the Portuguese and Qing empires, to a Japanese colonial model for the expansion of its Great East Asia Co-Prosperity Sphere, to a tentative militarized base for the restoration of the ROC, to a sustainability-oriented island democracy defending itself against multiple threats. Through all those transformations, Taiwan's power system subsequently served different national purposes in response to the contextual changes over time. At the same time, as this dissertation will explain by examining the different energy visions of various groups, TPC’s operating logic to a certain extent became fixed, with the sunk costs and physical limitations of energy infrastructure generating path dependencies that have cemented the island’s reliance on hydrocarbons. To explain the historical actors’ agency and the “carbon continuity” in Taiwan’s past energy transitions, the following section begins with an overview of the island's colonial

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[5] The data is calculated from TPC’s official record of the electricity generation by energy source over years by summing up the shares of gas-, coal-, and oil-fired power generation.

pasts and presents the continuing political unrest and social tensions that shaped the early formation of the TPC system.

1.1 Taiwan as a Global Island in reflection of its energy history

This small island nation has long represented a junction of circulated goods, technology, and heterogeneous actors from across the globe. It should be noted, however, that this diversity emerged from successive authoritarian regimes and great power competition. Taiwan's unique position in global networks can be traced to its colonial history, which could be broken into pre- and post-1860s eras in terms of Taiwan's position in global commercial networks. In the pre-1860s era, the imperial competition between the Dutch Republic (1624-1662) and the Spanish Habsburgs (1626-1642) over the ruling power of "Formosa" mainly concerned the establishment of a trading base and administrative centers on the commerce routes between China and Japan.[6] Taiwan's trading network was further expanded once the Qing dynasty took over the island in the 19th century, and so with it the growing export of raw materials such as tea, sugar, and camphor.

The Qing dynasty signed the Treaty of Tientsin in the early 1860s, which forced Taiwan's ports to open for commerce at the request of the British Empire. The treaty also opened the door for Taiwan to join the global coal-fueled economy. As a result, the treaty ports such as Keelung and Tamsui near coal mines in the northern region functioned as a coal refueling stations on American, British, and French steamship routes to Japan or China.[7] Coal as well as other commodities remained vital in the ensuing Japanese colonial period after the 1894 Sino-Japanese War. In Chapter 2 I will discuss how Keelung's social, economic, and port-city landscape were shaped by the coal industry after the Second World War. As this dissertation will argue, it is essential to situate the energy past in the context of transnational networks to understand how domestic coal became an option in the first place, and the different historical actors' agency in managing the coal industry.

The early trade in raw materials and coal suggests Taiwan was a site of intensive exploitation of local resources, which brought continuous exertion of imperial rule to the

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[6] Tonio Andrade, "The rise and fall of Dutch Taiwan, 1624-1662: Cooperative colonization and the statist model of European expansion," *Journal of World History* 17, no. 4 (2006): 429-50.

[7] A pioneering work on the history of Taiwan's coal trades and business in the 19th century, see Chia-mo Huang, *甲午戰前之臺灣煤務* [Taiwan Coal Affairs before the Sino-Japanese War], vol. 2 (Institute of Modern History, Academia Sinica, 1982), 315. Those geologists that were sent to Keelung to conduct surveys not only came from America, British, or France. According to Yu Wen-tang's archive research on the Prussian's official records such as the Prussian Expedition to East Asia (Die Prueßische Expedition nach Ost-Asien, 1859-1862) and confidential negotiations with the Qing dynasty about the navy base, Prussian's booming industrialization also sought to occupy Taiwan in the same period. See Wen-tang Yu, "19 世紀普魯士統一德國前對臺灣的覬覦 (1850-1870)," [Prussia's coveting of Taiwan before unifying Germany in the 19th century (1850-1870).] *國史館館刊*, no. 58 (2018): 1-3+5-68.

island and made Taiwan a "Global Island."[8] Taiwan then became not only an international crossroads for trade and an essential strategic stronghold during wartime, but also a hub of transnational knowledge exchanges in resource extraction. Such historical continuity from its colonial pasts and interconnectedness with the global economy substantially influenced the formation of Taiwan's energy infrastructure, for example, its electricity system underwent a significant extension in the 1930s when the Japanese empire fought toward another territorial expansion in Southeast Asia.[9]

Taiwan went through its first phase of electrification during the Japanese-ruled period. Since the late 1890s, small-scale generators were installed in municipality-owned utilities, private utilities, lighting companies, and factories. The biggest shareholders in most of the private companies were Japanese elites who often ran other businesses in the local area, such as the wood trade, or Japanese politicians who did not even live in Taiwan.[10] The electricity system was thus, originally regionally-based and disparate. What changed the physical and ownership structure of the power system was the construction plans for the Sun Moon Lake power plant with a capacity of 100,000 KW, which came into the picture in the 1910s, and the Japanese Empire's South-forward policy framework.

Like many countries' power systems in early developmental stages, large-scale hydropower plants relying on long-distance transmission lines often stimulate system integration across areas. The Sun-Moon Lake project was claimed to be one of the most massive engineering tasks within the Japanese Empire in the 1930s.[11] With its completion in 1934, three years before the beginning of the Second Sino-Japanese War (1937-1945), the hydroelectricity generation system became Taiwan's baseload power source. Furthermore, it also generated the need for a cross-regional grid and a centralized power system. To handle the high financial cost of the Sun-Moon Lake project and the ensuing construction of the first 154KV transmission line along the west coast, the Taiwan Denryoku Kabushiki Kaisha (TPC's predecessor) was formed earlier in 1919 and underwent a gradual acquisition of the initially

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[8] See Min Guo et al., *"Global Island: Taiwan and the World" Workshop Report*, Taiwan Studies Program, University of Washington (December 7, 2018 2018), https://jsis.washington.edu/taiwan/2018/12/07/global-island-taiwan-and-the-world-workshop-report/.

[9] The characteristic of a Global Island provides many insights for infrastructural studies not only in Taiwan but also in contemporary East Asia. See Max Hirsh, Angela Ki Che Leung, and Izumi Nakayama, "Infrastructure, modernity, and the technologies of everyday life: Insights from a collaborative research project on the making of modern East Asia," *East Asian Science, Technology and Society: An International Journal* 14, no. 3 (2020): 507-21.

[10] For more details about the system integration process, see Zheng-xian Wu, "民營電氣會社之發展與整併," [The development and merger of private electricity utilities.] *Newsletter of Taiwan Studies*, no. 113 (2019): 12-14.

[11] Another engineering task was the Yalu River power plant in North Korea. See Aaron Stephen Moore, ""The Yalu River Era of Developing Asia": Japanese expertise, colonial power, and the construction of Sup'ung Dam," *The Journal of Asian Studies* 72, no. 1 (2013): 115-39; Chung-li Wu, "Local factions and the Kuomintang in Taiwan's electoral politics," *International Relations of the Asia-Pacific* 3, no. 1 (2003): 89-111.

disparate regional utilities. The establishment of an integrated power system helped to boost the growth of heavy industry in the southern region and incorporate Taiwan's productivity into the Japanese Empire's vision for the Great East Asia Co-Prosperity Sphere.

However, before a cross-island electricity system could be built, many substations and outdoor switchyards were seriously damaged when Taiwan fell victim to the Allies' strategic bombing near the end of the Second World War. After the ravages of war and the handing over of power to Chiang Kai-shek's Nationalist Party (the Kuomintang or KMT), the National Resource Commission (NRC) took over the Japanese Imperial industries as requisitioned properties, including the TPC, and facilitated rehabilitation programs.[12] As the major government agent in overseeing these programs, NRC was initially established in 1932 and consisted of educated engineers in charge of industrial planning in Nationalist China. Even though studying abroad was enormously costly and greatly restricted by the government in wartime, many NRC members were sent to the U.S. or Europe to further their training. They then came back to fulfill their duties by being appointed to Taiwan and cities in mainland China to manage property takeover (including schools, banks, power plants, and mining fields). Most of their missions were to direct the repair of, and raise productivity across, industries destroyed by war. NRC's role in mobilizing energy sources constituted a specific energy politics culture on both sides of the Taiwan Strait and continued to influence the diverging paths of both the Communist and Nationalist regimes. I will elaborate this point further in section 1.3. First, though, a general layout of the KMT's ruling structure and government bodies regarding energy decision-making will help readers understand Taiwan’s technocratic system of energy governance and the tensions within it.

To cover the massive military expenditure at the front line of the ensuing Civil War (1945-1949), a temporary government body was established, the delegated Taiwan Provincial Administrative Executive Office. They handled the Japanese assets and launched a repair of the power system as its primary task to restore the island's productivity. After the Civil War, it was renamed the Taiwan Provincial Government, based on Nationalist China's territorial vision, and, thus, subordinated to the Chiang-directed Central Government. This governing structure remained in place with the Central Government's relocation to Taiwan, resulting in an obsolete layer of governance. Authorities and financial resources were distributed through the structure, while the relatively profitable industries, including the TPC, were put in the central government's hands. Tensions across the division between central and provincial government-led sectors would cause prolonged debates, such as on coal management issues addressed in chapter 2.

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[12] The National Resource Commission was a state agency established in 1932, it organized a supervisory committee in TPC to direct the administrative procedures of handing over during the transition period. This task was officially completed with a company restructure in 1946.

Contested interests did not only exist due to the organizational design. The faction based KMT polity operated in a hierarchical order from the highest political leadership (Chiang's family) to the upper echelon of statesmen at the ministry level, to agencies such as the NRC. What kind of energy exploitation plans would best fit the national interest were discussed through the three levels. During such meetings, directors of the central- or provincial-owned enterprises were not left out but rather engaged closely with the state industrial policy planning agencies, especially the Ministry of Economic Affairs (into which NRC was reformed as a subsidiary division overseeing nationalized enterprises in 1949), the Council for United States Aid (CUSA), and financial institutions in accordance with the CUSA such as the Economic Stabilization Board (ESB).[13]

Another important actor of the technocratic system was the American consultant company, J. G. White Engineering Company (JGW), that came with U.S. aid. As an ally in the anti-communist front in East Asia, the Nationalists' Republic of China (ROC) received U.S. aid (1951-1965) after the outbreak of the Korean War to begin their economic rehabilitation plans. Financial loans and technical assistance programs were launched via the aid, in which resources were significantly devoted to the TPC system's rebuilding and further expansion.[14] JGW was mandated with supervising the granted projects' execution and construction on behalf of CUSA. To acquire financial support, the TPC engineers delivered general reports, statistics on electricity demand and supply by sector and generating type, and development agendas as requested. In return, the JGW engineers assessed their proposals' economic and technical feasibility and merits. Their influence was not just confined to a single electricity sector. JGW also assumed the role of bridge between different industries. They were invited to almost all the assessment meetings of the working groups initiated by the CUSA across various targeted industries and government agencies.

In short, statesmen, bureaucrats, engineers, and transnational consultants exchanged ideas among these government bodies. However, while engineers were admitted to the channels and agency to realize their ideal power system, they also served as part of a state machine with structural limits. At the local level, contested scenes occurred regularly, such as the competing interests among TPC, the cement industry, iron manufacturing, and railroad administration regarding domestic coal utilization, as seen in chapter 2. At the international level, as the opening of this introduction chapter already hinted, when the Nationalists' ruling legitimacy was threatened by Taiwan's changing geopolitical situation, the regime would impose specific impacts on TPC's energy decisions.

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[13] See for example in the discussions about the supplying issues of domestic coal, the ESB held several meetings with CUSA, JGW, Taiwan Bank, CPC, and so on during 1951 and 1956. "礦業：會議記錄 [Mining industry: Minute of meetings]" *行政院經濟建設委員會 [Council for Economic Planning and Development]*, Academia Historica Collection, no. 040-010409-0013, Academia Historica.

[14] Wan-wen Chu, *台灣戰後經濟發展的源起: 後進發展的為何與如何 [The Causes of Taiwan's Postwar Economic Growth: The Why and How of Late Development]* [The Causes of Taiwan's Postwar Economic Growth: The Why and How of Late Development] (Linking Publishing, 2017), 521.

The technocratic system within the KMT regime underwent significant change during a series of diplomatic setbacks in the 1970s, resulting in the subsequent loosening of social and political control in the 1980s. Energy issues were specifically intertwined with pro-democracy movements led by the Democratic Progressive Party, especially regarding TPC's construction plans for nuclear power plants. The tide of democratization had long-lasting implications over several decades for Taiwan's current energy debates. For instance, when the Democratic Progressive Party (DPP) ended the KMT's rule in 2000, the newly elected president announced the termination of the fourth nuclear power plant project. In fact, one of the DPP's leading platforms today is to phase out nuclear power and replace it with alternative renewables. The DPP administration further formulated the "nuclear-free homeland by 2025" policy in 2016, targeting that 20 percent of Taiwan's power generation should come from solar and wind energy. This substantial turn toward renewable energy will be detailed in chapter 4.

To summarize, understanding Taiwan's past energy governances and choices is to delve into the mindsets of historical agents and their struggles among different groups or in the face of certain threats (such as possible warfare during the Taiwan Strait Crisis in the 1950s) and opportunities (e.g., the rescinded US aid programs). Furthermore, as my dissertation argues, the materiality of energy carriers and the infrastructural systemness, which both facilitate/bind their agency and capacity to deal with those situations, will help explain how Taiwan's governing logic varied and adapted to changes over time. This analytical approach is essential not only for studying Taiwan's energy pasts but also for better understanding the politics behind Taiwan's current ecological dilemmas of renewable transition in terms of the large-scale appropriation of land for wind turbines or solar panels, the corresponding and supposedly temporary dependence on imported natural gas (as detailed in Chapter 5), and the debates on the utilization of nuclear power (see in Chapter 4). By historicizing Taiwan's past energy transitions and exploring the tensions within, my dissertation offers a different perspective from the orthodox explanations of the drivers of energy transitions and argues for a systemic approach to understanding transition mechanisms.

1.2 Energy transition studies and conventional explanations

Energy transitions can be understood through different lenses and at different scales. A general definition of an energy transition refers to the changing energy sources for production and use in different industrial, electricity, and transportation sectors.[15] Meanwhile, a growing body of literature on transitions also shows that transitions often involve delicate and complex management in replacing/introducing energy technologies, infrastructure, regulations, industrial activities, and household appliances within the incumbent energy sector in response

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[15] Vaclav Smil, *Energy Transitions: History, Requirements, Prospects* (ABC-CLIO, 2010), 178.

to certain challenges or problems.[16] The triggers, barriers, and pathways toward the regime's shift are widely discussed from different aspects. For example, since the 1970s, as Kathleen Araújo observes, research on alternative fuels and governance started to emerge as the rising oil price became a national threat.[17] Yet, in recent years, there has been a significant shift in the focus of energy transition studies. Rather than solely studying specific energy sources, such as the coal question or oil crisis, there has been an increased interest in examining the dynamics of incumbent socio-technical energy systems, complexities, and regimes. This shift in focus of energy studies reflects an understanding that energy systems are not just about physical resources but also include the interplay between various technical and non-technical components.[18]

In order to grasp the diverse set of historical actors and their interactions across multiple technological systems, many researchers have applied the Multi-Level Perspective (MLP) framework to represent the mechanism of radical or incremental changes at three scales: niche, regime, and landscape. Socio-technical systems constitute the regime level within the MLP model. The idea refers to a constellation of actors, their binding routines, and technical elements mutually supporting the exploitation of a particular energy mix. Through the MLP model, researchers can identify and categorize the individual or organizational actors, events, technologies, and their interactions into different levels to depict the timeline of a (un)successful transition pathway.

For instance, Geert Verbong and Frank Geels give an example of applying MLP to explain why the relative share of renewable energy in the Dutch electricity sector remains lower than in other neighboring countries despite several attempted efforts.[19] They first identified a crucial turning point in the 1960s with the introduction of natural gas and nuclear projects into the Dutch electricity system that destabilized the incumbent socio-technical regime with the state's interventions. Observing the subsequent regime changes, their work describes the

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[16] Marten Boon, *Multinational Business and Transnational Regions: A Transnational Business History of Energy Transition in the Rhine Region, 1945-1973* (Routledge, 2018), 250; Gavin Bridge, Begüm Özkaynak, and Ethemcan Turhan, "Energy infrastructure and the fate of the nation: Introduction to special issue," *Energy research & social science* 41 (2018): 1-11; Margarita Balmaceda et al., "Energy materiality: A conceptual review of multi-disciplinary approaches," *Energy Research & Social Science* 56 (2019): 101-220.

[17] Kathleen Araújo, "The emerging field of energy transitions: progress, challenges, and opportunities," *Energy Research & Social Science* 1 (2014): 112-21.

[18] Geneviève Massard-Guilbaud, "From the history of sources and sectors to the history of systems and transitions: how the history of energy has been written in France and beyond," *Journal of Energy History*, no. 4 (2018): 1-37; Gordon T Goodman, Lars A Kristoferson, and Jack M Hollander, *The European Transition from Oil: Societal Impacts and Constraints on Energy Policy* (Academic Press, 1981), 338; Leah C. Stokes and Hanna L. Breetz, "Politics in the US energy transition: Case studies of solar, wind, biofuels and electric vehicles policy," *Energy Policy* 113 (2018): 76-86; Erik van der Vleuten and Per Högselius, "Resisting Change? The Transnational Dynamics of European Energy Regimes: Erik Van Der Vleuten and Per Högselius," in *Governing the energy transition : reality, illusion or necessity?*, ed. G.P.J. Verbong and D. Loorbach (Routledge Taylor & Francis Group, 2012), 86-111.

[19] Geert Verbong and Frank Geels, "The ongoing energy transition: lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960–2004)," *Energy policy* 35, no. 2 (2007): 1025-37.

influence of oil crises in the 1970s, market liberalization in the 1990s, and Europeanization as exogenous factors at the landscape level. In conclusion, they closed their discussion with a short analysis of the developing potential of wind, biomass, and solar PV within socio-technical regimes. They pointed out that the reason behind the Dutch's relatively lower percentage of renewable energy is that the network later forged under the state's energy policy and electricity law had diverted attention and resources to the decentralized combined heat and power plants. Subsequently, the regime left much less room for developing other renewable energy technologies at the niche level. Therefore, biomass seemed to be the most feasible option as it could be easily integrated into the existing electricity system with the co-firing coal-fired power units. The importance of such adaptability and access to the existing grid in shaping the fate of energy technologies across levels was highlighted in their research. What I would like to address further is that we should also consider their compatibilities with other supporting industrial sectors and technological systems that significantly contribute to an energy regime's self-reinforcing mechanisms, or what is often called "lock-in effects."

In the MLP model, however, such interactions between multiple systems are often neglected. Considering such a caveat, Timothy Foxon proposes the analytical approach of a coevolutionary framework to understand the configuration of ecosystems, technologies, institutions, business strategies, and user practices, which shape the transition process together.[20] Based on the evolutionary economic models, Foxon views the various practices of the sociotechnical elements and ecosystems in multiple interdependent relationships. Their causal interactions would then contribute to industrial, technological, institutional, or ecological changes.

For example, Stathis Arapostathis, Peter Pearson, and Timothy Foxon's case study of the conversion and integration of the manufactured gas and natural gas system in the United Kingdom after the Second World War applies a systems integration approach to examine how such a radical transformation was made possible in terms of the re-arrangement of governing structure (as happened in Taiwan's context, too) and the spatial extension of the gas system.[21] The conventional town gas system used to dominate the UK's heating and industrial sector but soon faced challenges from the growing scarcity of coking coals for producing manufactured gas and the competition with electricity and oil since the 1960s. In turn, a more centralized governing regime came into being when the exploitation of North Sea natural gas began, which paved the way for introducing LNG into the UK's energy mix and its new natural gas grid along with the electricity network.

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[20] See Timothy J. Foxon, "A coevolutionary framework for analysing a transition to a sustainable low carbon economy," *Ecological economics* 70, no. 12 (2011): 2258-67.

[21] For more details, see Stathis Arapostathis, Peter J. G. Pearson, and Timothy J. Foxon, "UK natural gas system integration in the making, 1960–2010: Complexity, transitional uncertainties and uncertain transitions," *Environmental Innovation and Societal Transitions* 11 (2014): 87-102.

The growing complexity and sophistication of the gas system in their story explain how an energy transition, in practice, entailed rearranging the physical and governing systems among manufactured gas, LNG pipelines, the electricity grid, and the oil system. Furthermore, through observing the system configurations, the authors not only argued for the importance of the systems integration dimension of regime construction in the MLP model but also indicated that instead of emphasizing the clean-cut breaching points within the niche, regime, and landscape level, transition studies researchers might better convey a dynamic image of transformation in terms of system adaptations.[22] In other words, they differ from classic MLP in considering transition as a series of breaching points marked by certain moments or historical actors' agency in the regime to counter the pressures from other sectors at different levels. My dissertation on Taiwan's multiple past energy transitions attempts to further their points, especially about the co-evolution of the oil, electricity, coal, gas, and nuclear regimes. By looking beyond a single power system and into the persistence and ruptures of the linkages among multiple (energy and non-energy) systems across energy transitions, the dissertation aims to understand how Taiwan's dependence on fossil fuels was created in the first place and how its systemic continuities or structural limits yield implications for contemporary renewable transitions.

In addition to the insights from the system integration approach, my dissertation illustrates the bridging of their linkages and the momentum of growth of Taiwan’s carbon dependency from a long-range perspective. Delving into the temporary or (more often) continuous utilization of water, wood, peat, coal, oil, gas, or nuclear in the generation of heat and electrical power, the historical approach enables scholars to situate and, thus, understand energy decisions in a specific social and local context and over different time horizons.[23] Perhaps more importantly, histories often show repetitive efforts and cumulative progress that might also lead to divergences. For instance, Anaël Marrec's work shows how prominent tidal energy converters once were in the French power system at the beginning of the 1900s.[24] As

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[22] Through their study of Greece’s gas regime for example, Fotopoulos, Arapostathis, and Pearson explained the idea of branching points as “…the critical junctures in which regime actors made decisions and/or competing logics emerged in response to external/landscape or internal pressures, and the ‘action space’ was re-shaped, influencing the choices made and the dynamics of the transition pathway along the now dominant governance logic.” For more discussions, see Yannis Fotopoulos, Stathis Arapostathis, and Peter J.G. Pearson, "Branching points and transition pathways in the Greek Natural Gas Regime, 1966–2016," *Environmental Innovation and Societal Transitions* 32 (2019): 74.

[23] Historians have been pressing the importance of a long-range perspective on energy transitions. See for example, Ute Hasenöhrl and Jan-Henrik Meyer, "The energy challenge in historical perspective," *Technology and Culture* 61, no. 1 (2020): 295-306; Ute Hasenöhrl and Patrick Kupper, "Historicizing renewables: issues and challenges," *History and Technology* 37, no. 4 (2021): 397-410; Michael Gismondi, "Historicizing transitions: The value of historical theory to energy transition research," *Energy Research & Social Science* 38 (2018): 193-98. Pierre Lamard and Nicolas Stoskopf, eds., *Energy Transition: A Historical Concept? [La Transition Energetique: Un Concept Historique?]*, Environmental and Society (Septentrion University Press, 2018).

[24] For more details, see Anaël Marrec, "Wave converters against energy systems? Le Minou’s ram and

France undertook standardization of its national grid, the relative lack of black and white coal in the northwest area encouraged a turn to blue coal and wave energy. Marrec notes that the state engineers' interest in developing tidal energy converters lay in the technical similarities with the conventional dam-hydropower system. For instance, it was the globally renowned dam architect André Coyne (1891-1960), who directed those experiments between 1925 and 1929. Although wave-converting technologies received less attention regarding systemic integration, they were still considered for the sake of local electrical companies' possible appropriations.

Marrec further argues that "the existence of an energy system presupposes a necessarily privileged interaction between energy converters at any moment in history. However, there is nothing obvious about this assumption: energy technologies have not always been homogenized within networks, and they are intertwined with other dimensions than energy."[25] The other dimensions could be geographical features, engineers' expertise, national interest, the consumption landscape, and competition and coordination among energy technologies. In line with Marrec's argument, this dissertation does not make assumptions regarding the "optimal energy mix" in Taiwan's past energy futures, instead, it will illustrate how those visions of certain energy sources, such as coal, oil, nuclear, and renewables, coincided with the social and political realities over time.

Research on Taiwan's energy transitions only began to emerge in recent decades, and often linked to the contemporary issue of decarbonization. For example, Chou Kuei-tien's research team at the Risk Society and Policy Research Center has discussed the possibility of escaping the lock-in effects of the entrenched network of a carbon-based production-consumption mode called the "brown economy," and sought ways to monitor and regulate the pollutants emitted from those major energy-intensive users through policy tools.[26] Yet, instead of taking the backdrop of such a carbon-intensive network for granted, my study intends to show the historical roots of that brown economy. These historic linkages are often missed in policy-oriented studies since scholars have tended to seek answers to Taiwan's previous energy decisions from the government's policy-planning body, which attained a dominant role in formulating energy policy only after 1968. Researchers rarely explore the changes between these periods nor challenge the assumptions behind the logic of their

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the Cattaneo Ondo-pump in the frame of French blue coal policy (1925-1945)," *Cahiers François Viète*, no. III-12 (2022): 49-72.

[25] See Marrec, "Wave converters against energy systems? Le Minou's ram and the Cattaneo Ondo-pump in the frame of French blue coal policy (1925-1945)," 51.

[26] For more works on similar issue, see Kuei-tien Chou, *能怎麼轉: 啟動臺灣能源轉型鑰匙* [How to Be [in] Transition: Initiate the Key Transition of Energy in Taiwan], vol. 3 (Risk Society and Policy Research Center, 2017), 288; Kuei-tien Chou, *Sociology of Climate Change: High Carbon Society and its transformation challenge* (National Taiwan University Press, 2017), 328.

chronological order.[27] Instead, various explanations derived from TPC's self-legitimating depiction have become conventional and shaped the recent energy debates in Taiwan.

Prior works on Taiwan's energy transition include works from the perspective of regional economic studies, marketing studies, regional studies, and science policy research.[28] Scholars associated with these literatures take different conceptual and methodological approaches according to their academic fields, but their claims regarding energy transitions can be divided into three main kinds of explanations. The first mode of explanation emphasizes the management of energy sovereignty and security of supply; these accounts usually derive from the historical events of the oil crisis in the 1970s and the major nuclear disasters at Chernobyl and Fukushima in 1986 and 2011. Managing "shortage" due to Taiwan's geographical limitation as an island without many hydrocarbon resources or a transnational grid contributed to their assertions that the diversification decision at those critical moments was a reasonable outcome. Such statements for explaining nuclear power's development in the 1970s or why Taiwan became highly dependent on imported fuels in the first place can be easily found in political propaganda promoting alternative energy and policy-oriented research.[29]

The second kind of explanation focuses on the logic of supply and demand along with the state's interventions behind each energy transition. This account treats the increased electricity demand from the industrial sector as the leading cause of Taiwan's energy transition. Due to Taiwan's dramatic economic growth during the 1960s-90s, the development of diverse power sources was necessary to guarantee a more "stable" energy supply that would prevent any power outage which could threaten Taiwan's industrial production.[30]

A third explanation of what directing Taiwan's recent energy transition, especially in terms of nuclear power's development, is the rising public pressure against the authoritarian regime since the 1980s. Environmentalists/activists and sociologists questioned the existing energy policy and protested importing hazardous pollutants from foreign petrochemical

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[27] See Wen-pin Weng, "A study of the Electric Energy' s Policy in Postwar Taiwan" (Master thesis, Feng Chia University, 2018); Tsai-yi Wu et al., "我國能源政策發展模式及其未來方向探討 [Discussion on our country's energy policy development model and its future direction]," [Discussion on our country's energy policy development model and its future direction.] *Quarterly Journal of Bank of Taiwan* (2012): 34-87.

[28] See David Angel and Michael T. Rock, "Environmental rationalities and the development state in East Asia: prospects for a sustainability transition," *Technological Forecasting and Social Change* 76, no. 2 (2009): 229-40; Frans Berkhout et al., "Sustainability experiments in Asia: innovations shaping alternative development pathways?," *Environmental science & policy* 13, no. 4 (2010): 261-71.

[29] See for example, Po-yao Kuo, *The Impacts of Energy Trends and Policies on Taiwan's Power Generation Systems*, Asian Growth Research Institute (2015); Amy J. C. Trappey et al., "An evaluation model for low carbon island policy: The case of Taiwan's green transportation policy," *Energy Policy* 45 (2012): 510-15; W. T. Tsai, "Current status and development policies on renewable energy technology research in Taiwan," *Renewable and Sustainable Energy Reviews* 9, no. 3 (2005): 237-53.

[30] See Yun-hsun Huang and Jung-hua Wu, "Energy policy in Taiwan: Historical developments, current status and potential improvements," *Energies* 2, no. 3 (2009): 623-45.

industries.[31] This increasing awareness of the uneven distribution of risks in pursuit of economic growth climaxed in the first massive anti-nuclear power movement in 1988. The severe fire at Taiwan's third nuclear power plant and the disaster at Chernobyl aroused street protests against the construction of the fourth nuclear power plant in Taiwan. The protests were organized by the Taiwan Environmental Protection Union (TEPU), which was established in 1987, right at the end of martial law, and they further demanded a decentralized energy system and the democratization of the electricity market. The serial social movements after the democratic transition represented different ideas of energy usage from a local perspective and has become one of the specific explanations for why Taiwanese energy policy changed in the late 20th century.

In general, these explanations share the argumentative strategy of framing the government’s energy decision a result of Taiwan’s geological limitations in terms of energy shortages and of economic, social, or global energy crises. This explanation in each case is that a post-catastrophic alarm brought about change; in Poskanzer's terms such explanations are "a weak ex-post facto argument."[32] These narratives emphasize international energy crises and regard energy transition as the solution for preventing the potential exhaustion of resources that could threaten "national security" and sustainable development. As if shifting Taiwan’s baseload power sources to oil, nuclear, natural gas, or renewables over time were all responses to the external influences and forces under similar concerns of “energy security.”

However, as Johannes Kester explored how the concept of energy security was coined and applied in different critical times in Europe, the idea of security changes due to the different framings of the governing strategies of the present energy activities based on system- or policy planners' forecasts and capabilities at hand.[33] Therefore, while energy security was often rendered as the cause of Taiwan's energy choices in the previous studies, my dissertation intends to explore the internal reasoning as how the TPC engineers and policymakers articulated and developed the idea of energy security to tackle not only the problems of "shortage" or "exhaustion" but, sometimes, to manage the abundance.

A recent study shares the same research interest in how such performativity was articulated in practice by taking Taiwan's recent renewable energy development as a case in point. Yang Chih-yuan used the socio-technical imaginary as a framework to elaborate the

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[31] See Ming-sho Ho, "Environmental Movement in Democratizing Taiwan (1980–2004): A Political Opportunity Structure Perspective," in *East Asian Social Movements* (Springer, 2011), 283-314; T. J. Price and S. D. Probert, "Taiwan's energy and environmental policies: Past, present and future," *Applied energy* 50, no. 1 (1995): 41-68.

[32] See Deborah Poskanzer, "The Future and the Environment: A History of Shared Expertise," in *Work in Progress: Economy and Environment in the Hands of Experts*, ed. Frank Trentmann, Anna Barbara Sum, and Manuel Rivera (Oekom Verlag GmbH, 2018), 205-32.

[33] See Johannes Kester, "Securing Abundance: The Politics of Energy Security" (PhD thesis, University of Groningen, 2016). Explorations on the concept formation of energy security can also see Aleh Cherp and Jessica Jewell, "The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration," *Current Opinion in Environmental Sustainability* 3, no. 4 (2011): 202-12.

threefold storylines of renewables in Taiwan.[34] One storyline is presented in the Taiwanese government's claims of a "power shortage" to shore up their incentives for nuclear power after the 2011 Fukushima accident. A second one comes from the feed-in tariffs committee, which frames green energy as a juvenile system that needs experts' control even if it's also a prominent solution for energy autonomy. Finally, Yang discussed the imaginary of renewables attached to multiple identities emerging from the local installation of customized solar farms after the catastrophic typhoon Morakot in 2009.[35] As Yang pointed out, various definitions of renewables exist in different social fields. Yang's analysis centered on the growing discourse of electricity shortage and its calculation of marginal usage to justify the government's energy policy at large. In so doing, the government plotted Taiwan's energy policy and the intense relation between nuclear and green energy power in terms of Taiwan's early development aims and the accompanying post-war technocratic system. Yang devoted his efforts to underlining how renewable energy technologies' suitability varied with different perceptions of various social groups, i.e., engineers, government, and the local community.

Clearly, opinions varied among different social groups. Even within the Nationalist regime, which was characterized as a developmental state led by technocrats, TPC engineers found that their interests contrasted with those of other technocrats or state agencies.[36] Moreover, contested visions could also be seen *within* the TPC engineers' community due to diverse training backgrounds and personal careers. By following Taiwan's energy system over a longer time horizon, I intend to contextualize the historical formation of the dominant position of conventional power-generating technologies to explain why renewables remained at the margin of the power system until the 2000s, and what turned the tide.

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[34] Refusing the unilinear discourse of progress, sociotechnical imaginaries offer a way to interrogate multifaceted technical projects at the state level and to view scientific knowledge and technical projects as embedded in social contexts, and *vice versa.* See Sheila Jasanoff and Sang-Hyun Kim, *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (University of Chicago Press, 2015), 364.

[35] Other pioneering works applying STS approach on Taiwan's solar power development and the invoked controversies can see Hung-jen Yang, "An actor-network analysis of the "Building Solar Farms over Fish Ponds" scheme: Local government, solar PV firms, and local farmers," *Taiwan Journal of Anthropology* 15, no. 2 (2017): 45-96; Chen Hui-ping, "Green technology and local use: An analysis of the photovoltaic socio-technical networks in Taiwan" (PhD thesis, National Taiwan University, 2015); Hua-mei Chiu, "漁電共生行不行 [Is Fishery and Electricity Symbiosis Feasible?]," in *科技社會人 4：跟著關鍵物去旅行 [STSers 4: Traveling with the Key Materials]*, ed. Wen-yuan Lin et al. (National Yang Ming Chiao Tung University Press, 2022), 50-64.

[36] Scholars coined the concept of the Developmental State to explain this concomitant development as the growth of the states and economic transformation in East Asia from the perspective of a world system since the early 1980s. Chalmers Johnson firstly developed this theory based on Japan's transition experiences in which the Ministry of International Trade and Industry (MITI), industrial policy, and public-private cooperation boosted significant domestic growth during the years 1925-1975. See in Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy: 1925-1975* (Stanford University Press, 1982), 412; Chalmers Johnson, "The developmental state: Odyssey of a concept," *The developmental state* (1999): 32-60.

Diverting attention from the state-centered analysis and crisis-responses modes of explanations for the changing energy reality, my study of Taiwan's case attempts to explore the decision-making mechanisms behind those different envisioned futures, and also the historical contingencies of past energy systems. With my historically grounded analysis, I will go beyond the "one-time" crisis-based explanations mentioned above and instead illustrate how crises were visualized and articulated in terms of "national interests" over the longer term, with engineers as the most prominent historical actors in that process of articulation. In the following section, I will elaborate on the insights I gained from works centering on the roles of engineers in building the national energy regime.

1.3 Engineers' role in the entanglement of energy carriers, socio-technical systems, and the nation in the making

> Just after the war, at the beginning of his time at Taipower Company, he [Sun Yun-suan] gathered around him hundreds of specialists and through tireless efforts restored 80 percent of the nation's electrical infrastructure in a five-month period, which had been destroyed during the war, – a powerful rebuke to Japanese taunts that Taiwan would return to the 'dark ages' within three months**.** [37]

From extraction to conversion and consumption of energy carriers, the engineer's task is to channel and maintain the flow of electricity through the power grid and fuel through the transportation network to serve certain social, economic, or political interests. Historical events (such as war) or external factors (severe weather or natural disasters) could disrupt the grid and fuel transportation network. For example, the tale of how Sun Yun-suan saved Taiwan from a complete blackout despite the war's ravages was widely circulated and conjured up his heroic image. The underlying political purpose of that tale was to show the legitimacy of the Nationalist party by degrading the Japanese contributions.[38] It was depicted as another significant triumph against the Japanese Empire after winning the Second War. However, such claims of "Sinofication" and denials of Japanese colonial legacies, as seen in the following

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[37] See similar appraisements in the biographies of Sun Yun-suan in Xiu-zhi Chiu, *我所認識的孫運璿: 孫運璿八十大壽紀念專輯* [The Sun Yun-suan I Know: Sun Yun-suan's 80th Birthday Commemorative Album] (Lucy Sun Hwang, 1993), 396. https://books.google.nl/books?id=WTx9AAAAIAAJ. Sun was one of the TPC engineers and the most influential technologist in Taiwan during the authoritarian regime. He became a well-known "statesman" when he moved through the ranks to the highest circle of policymaking by serving as the Premier of Executive Yuan (or Cabinet) from 1978 to 1984.

[38] Since Taiwan had long been a colony under different ruling powers before the Second War, the island had gathered Austronesian peoples and immigrants from the South Pacific over time. The KMT was also one of the exogenous polities which exerted national assimilation strategies among people. The tensions between mainlanders and Taiwanese were further amplified within the international anti-communism sphere, and caused large-scale suppressions as known as the February 28 massacre in 1947 and the following White Terror period (1949-1991). The consequences continue to reverberate in political affairs until today.

chapters, became a secondary priority in the post-war rehabilitation plans. The primary goal behind taking over the Japanese assets while maintaining state control over (and revamping) most industrial sectors was that the KMT could continue allocating more than half of the national budget to military expenses. This was necessary as troop landings and bombings against the Communists still occurred in the 1950s. Rebuilding, expanding, and regulating the power system was, thus, at the heart of the KMT's national goal of reunification.

The task of (re)constructing Taiwan's power system was entrusted to engineers from diverse national and training backgrounds. In the early post-war years, the vertical integration of electricity generation, transmission, and distribution required contributions from various engineering disciplines, from electrical to civil to hydraulic engineering. The composition of TPC engineers' expertise changed as the power system evolved with the integration of new energy technologies. For example, TPC engineers in the thermal and nuclear power generation sector who learned by doing during the installation and operation of steam power generators from their foreign contractors gradually outnumbered the staff in the hydraulic engineering sector since the 1950s. Their contested views on what constitutes an "optimal energy mix" provides crucial sources for my study on the shifting orientation toward imported fuels, nuclear power, and renewable energy and, thus, will be shown in the remaining chapters.

As the beginning of this chapter hinted, TPC engineers did not always have a free hand in directing the system’s development and making energy decisions. Examining to what extent their decisions materialized and to what end is essential in enabling this study to argue with the current state-centering approach in understanding Taiwan's energy transitions. So far, historians have only offered a simplified view of engineers' engagement in diplomacy and politics that exclusively considers engineer-statesmen who climbed to the ministerial rank, such as Sun Yun-Xuan.[39] The KMT's top-down ruling structure has led historians to explain "Taiwan's economic miracle" (Taiwan's sustained growth with a trade surplus after 1970 and transformation into a model for other developing countries) solely in terms of the efforts of statesmen and state engineers.

Current historiography, therefore, depicts a chronology drawn in line with significant policy decisions. Because Taiwan's first comprehensive energy policy was made public in 1968, only a limited literature addresses earlier energy decisions dedicated to the first significant shift from hydropower to a coal- and fuel-oil-based power system. This dissertation aims to fill the gap by considering less-prominent engineers' decisions – i.e., the actions of engineers making policy at the grassroots rather than just the actions of engineer-statesmen issuing (and/or following) directives from the political elite. The cooperation among TPC engineers, Chinese Petroleum Company (CPC) managers, directors of government bodies, and

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[39] Using materials like personal diaries and training reports in the 1940s-1950s, Sun’s visions and career as TPC’s key figure at the time were thoroughly documented in Lan-fang Lin, "The National Resources Commission's takeover of Taiwan Power Company in the early post-war period (1945-1952): Technology and engineers," *Bulletin of the Institute of Modern History Academia Sinica*, no. 79 (2013): 87-135.

transnational consultants established a specific energy politics culture which will be the focus of this dissertation in explaining Taiwan's past energy decisions.

The overlapping roles of TPC chief engineers and managers as NRC members or consultants in industrial planning resembles the "carbon technocracy" depicted in Victor Seow's study of the extraction and management of China's largest coal collier in Fushun under the Nationalist regime in the prewar years (the 1920s to the 1940s).[40] Seow's thorough examination shows readers how the Soviets, Japanese, Nationalists, and finally, the Communists applied strategies and technologies from the early 1900s to the 1960s in handling the production and materiality of coal, including its varied heat value, ash, and moisture content distributed in different seams. In synthesis, Seow links the idea of technocracy closely with carbon resources and terms such connections "carbon technocracy," defined as "a technopolitical system grounded in the idealization of extensive fossil fuel exploitation through mechanical and managerial means… that is concurrently an alternative account of state formation in modern East Asia and a transnational history of technology."[41] The NRC was the primary institution that forged the realization of carbon technocracy.

In contrast, Ying Jia Tan in *Recharging China* rejects such a definition in his work on the struggles of the same group of NRC engineers (who came to serve the Communists instead) in Shanghai who managed thermal power units during the ensuing Civil War.[42] For Tan, these engineer-bureaucrats, to use his phrase, were intrinsically bureaucrats. Instead of devoting themselves to the coal industry, their primary goal was to prevent more financial loss from the counterattacks of the Nationalists; thus, instead of building more power plants to revamp the city's industrial production, they turned to managing the demand side by distributing the load over a variety of working schedules throughout the city. Achieving autarky and satisfying immediate demands mattered much more than efficiency, optimal energy choice, or generating units. It is not my intention to resolve Tan and Seow's divergent understandings, but rather to build on their empirical works and insights about engineers' agency in helping to achieve national goals.

Another reason for easily overlooking engineers' influence was probably because of the Nationalists' strict control over national enterprises and their resultant top-down energy decision-making approach. Yet, Lino Camprubí's work offers a different picture under similar circumstances – i.e., an alternative path that Taiwan could easily have followed.[43] Camprubí

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[40] Victor Seow, *Carbon Technocracy: Energy Regimes in Modern East Asia* (University of Chicago Press, 2022).

[41] Aaron Stephen Moore, *Constructing East Asia: Technology, Ideology, and Empire in Japan's Wartime Era, 1931-1945* (Stanford University Press, 2013).

[42] Referring to Seow's dissertation on carbon technocracy, Tan noted that his observation with the engineers' management in the wartime Shanghai were not about the strategic deployment of coal nor about the systemic thinking in terms of a stable power output on long term basis. See more in Ying Jia Tan, *Recharging China in War and Revolution, 1882–1955* (Cornell University Press, 2021).

[43] Lino Camprubí, *Engineers and the Making of the Francoist Regime* (MIT Press, 2014), 312.

has written about the negotiations and competition between two nominally autarkic state bodies over control of the geological and hydrological characteristics of the Noguera Ribagorzana basin. Staff engineers in the two institutions sought a productive Spain founded either upon agriculture (water for irrigation) or industrialization (water for power generation); the difference in their ultimate aims resulted in debates over hydrological flows and regulation of water levels of dams and competition for political and legal power over the Noguera's waters.

As Camprubí shows, most historians' perception that army engineers' ideas for dams' construction were mainly in the national interest are a misunderstanding fed by the "totalitarian" ideology of the regime. In depicting such a process of horizontal integration, in which cross-agency competition over the authority to direct the project took place, and experts enrolled other actors to help them transform Spain's landscape into their idealized visions, Camprubí enriches our understanding of engineers' engagement in building the Francoist regime by underscoring their different aims and expertise. My study similarly examines engineers in the context of Taiwan's authoritarian state, where there was also significant competition among different organs of the state regarding energy issues.

By drawing on Tan and Seow's studies of Nationalist China and Camprubí's of Francoist Spain (where the evolution of state authority followed a timeline almost identical to that of the KMT regime), my dissertation sheds light on their understanding of engineers' agency and their attempts to control and transform the energy landscape through cooperation with other historical actors in order to rebuild the nation-state. For example, chapter 2 shows engineers spent as much time in handling the interruption in fuel transport as they did in designing the power plants. The coal famine in Nationalist China happened not because of shortage but because of the problematic railway situation, as Seow has claims, which also applied in Taiwan and made TPC engineers begin to consider imported oil. Subsequently, the intensified utilization of hydrocarbon fuels was accompanied by the densification of the supporting infrastructural network. Accordingly, pollution and the TPC system's vulnerability were exposed to the public as the network extended across the island. In turn, TPC engineers confronted the heterogeneous actors and coalitions among residents, fishers, DPP politicians, and environmentalists, as discussed in Chapters 3 and 4. It is important to render the growing environmental movements, anti-nuclear protests, and pro-democracy movements in the 1980s as a collective response to the carbon-intensified network to understand the multifaceted pressure destabilizing the socio-technical regime.

Tracing the configuration of multiple systems, or horizontal integration in Camprubí's words, allows my study to map out such a tightly coupled network's historical formation and lock-in mechanism. This coevolutionary perspective requires a systems-level view. In the following section, I present the conceptual tools I used to understand Taiwan's energy system and how the system's inertia entrenched a fossil-fuel-based network.

1.4 Conceptual tools for understanding the evolving fossil-fuel-based network

Applying a historical approach, I examine Taiwan's multiple energy transitions after the Second War to understand how various actors envisioned the island's energy futures over time and how those visions were entangled with Taiwan's post-war economic rehabilitation, diplomatic crisis, democratization, and escalating nuclear disputes in the post-Fukushima Era. Such entanglement of energy technologies and nation-building has been explored in various national political contexts.[44] In this dynamic entanglement – what Gabrielle Hecht calls "technopolitics" – the *technological* aspect is crucial to understanding engineers' operational logic of power systems.[45] The technological underpinnings of political decisions (and vice versa) are also a familiar theme in the field of Science, Technology, and Society Studies (STS). The power system is one of the major infrastructures characterized by long-range investment and vested interests, its construction and resilience offer researchers cases in point to explore the co-evolution of socio-technical systems.

Throughout my dissertation, I use the concept of infrasystems to describe how the TPC system co-evolved with other infrastructures, which created a self-reinforcing effect and resulted in the current "carbon-intensive" network. Derived from the early work on the Large Technical System (LTS) framework, Arne Kaijser coined the concept of infrastructural systems (or infrasystem) to highlight the materiality and inter-reliance among infrastructure systems and their associated actors.[46] Initially, the LTS framework proposed by Thomas P. Hughes helped to explain the evolution and variance of a rather complex technological system. Hughes' work examined the varied development paths of the electricity systems in the US, Britain, and Germany.[47] LTS offers a toolbox for researchers to analyze the various social, environmental, and political controversies surrounding a particular technology. Scholars, especially historians of technology, have applied this approach to examine the evolution of mega-infrastructure projects such as telecommunication, transportation, and power systems. To explain the configuration of society and technology, LTS employs concepts such as system

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[44] See for example, Camprubí, *Engineers and the Making of the Francoist Regime*; Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity After World War II* (MIT press, 2009), 496; Q. C. van Est, "Winds of change: A comparative study of the politics of wind energy innovation in California and Denmark" (PhD thesis, International books Utrecht, 1999); David G. Victor, Amy M. Jaffe, and Mark H. Hayes, *Natural Gas and Geopolitics: From 1970 to 2040* (Cambridge University Press, 2006), 508.

[45] Gabrielle Hecht, *The Radiance of France, new Edition: Nuclear Power and National Identity After World War II* (MIT press, 2009).

[46] Arne Kaijser, "Fighting for Lighting and Cooking: Competing Energy Systems in Sweden, 1880-1960," in *Technological Competitiveness: Contemporary and Historical Perspectives on the Electrical, Electronics, and Computer Industries*, ed. William Aspray (IEEE Press, 1993), 195-207; Arne Kaijser, "The helping hand. In search of a Swedish institutional regime for infrastructural systems," *Andersson-Skog, L. & Kranz, O.(red.), Institutions in the transport and communications industries (Canton, Ma)* (1999): 223-44; Arne Kaijser, "Redirecting Infrasystems towards Sustainability," in *Individual and structural determinants of environmental practice* (Routledge, 2017), 152-79.

[47] Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Johns Hopkins University Press, 1983), 474.

builder, reverse salient, element, and seamless web. A system builder (a role TPC assumes in this dissertation) is a manager or entrepreneur of a technological system who ensures the realization and durability of such a system. In practice, when the system's components cannot meet the elements' requests (which could come from regulatory bodies, markets, or investors), the "laggard" components become reverse salient, i.e., problems waiting to be solved. In general, the theoretical framework of LTS shows how technical systems achieve enduring growth by examining the interplay among heterogeneous actors and artifacts.

While the LTS approach focuses on evolving a socio-technical system by tracing system builders' coping strategies, the infrasystems approach deals with multiple public service systems by examining the systems' interrelation and adaptation. An infrasystem comprises networks with assessable nodes and linkages carrying flows (in physical or nonphysical forms of cargoes, energy, or information). That is, the infrasystems approach studies how these infrasystems and their governance logic changed the surrounding social relations with their geographical extension. Together, the interplays of infrasystems served the state's purposes for increasing military strength, economic growth, social welfare, and international competitiveness over time. Emphasizing infrastructural relations, the concept of infrasystems directs scholars' attention to the system itself and the economic value and political power that is formed and redistributed through the physical infrastructure and its connections. This viewpoint aligns with historians' works on how the energy distribution network's materiality impacted the political-economic regime and vice versa.

Christopher Jones's book *Routes of Power* is especially relevant to my dissertation in this regard.[48] Jones illustrates the historical context of the energy transitions in North-eastern America through the expanding transportation network of fuels (from wood to anthracite coal, oil, and electricity). He notes that the configuration of transport infrastructure and modes of trade across the energy transitions resulted in an uneven distribution of wealth and hazards along the canals, railroads, pipelines, and transmission wires. In the story of the transition from anthracite coal to oil, Jones states that "the liquid nature of petroleum, combined with the lack of development in western Pennsylvania, made transport an acute challenge… it was easy enough to produce oil, but far more difficult to convey it to the consumer." In Jones' words, the subsequent competition among profit seekers, instead of nation-builders, had been about the domination of railroads. It was not only a transition of energy use but also a transition from organic to mineral transport in the mid-19th century. Jones highlighted the capacity of infrastructural links to explain how the exploitation of different fossil fuels and the spread of connected appliances in factories and households made it possible to create or change incumbent energy regimes.

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[48] Christopher F. Jones, *Routes of Power: Energy and Modern America* (Harvard University Press, 2014), 312.

Once again, such a characteristic of infrastructure was relatively absent in the MLP model perhaps due to its presumptions of infrastructure. When it comes to the discussion of infrastructure, the MLP approach tends to focus on the actors’ practices and critical moments shaping the infrastructure at the regime level instead of seeing it as the building blocks of a lasting landscape.[49] If one understands transitions in the latter situation, transition pathways would mean the “reinfrastructuring” process and, thus, be able to capture how the infrasystems create opportunities for change and trigger cross-levels interactions and coevolution of heterogeneous elements.[50]

Therefore, this dissertation stands in line with Jones' emphasis and applies a systems integration approach through the concept of infrasystems. Chapter 2 unfolds the story of how TPC engineers argued with another major coal consumer, the Taiwan Rail Administration (TRA), while pushing for the TRA system's expansion in terms of its freight capacity to carry more coal to support the remotely located thermal power plant. I explain how the coal management problem later resulted in TPC engineers’ considering imported oil because its fuel oil supplier, the Chinese Petroleum Company, was experiencing substantial growth concurrent with the port facilities' expansion in the late 1960s. As TPC's fuel network extended through railways and waterways, ensuring that the continuing flows and storage capacity became essential to achieve power supply stability. Accordingly, their energy options were bounded by such structural limits. In chapters 3 and 4, I explain how the tightly coupled carbon-intensive infrasystems shaped the development scale of nuclear power and renewable energy. In short, applying the concept of infrasystems enables my dissertation to contextualize TPC's energy decisions in relation to its supportive infrastructural systems, which greatly influence Taiwan's current renewable transition and dependence on imported hydrocarbons.

Tracing TPC engineers' changing mindsets regarding the optimal energy mix over time and exploring how exactly their concerns reached the cabinet or cross-government sector meetings of the major infrastructure programs are thus the major challenges for my study. In order to map out Taiwan's pathway toward a carbon-intensive network, my dissertation mainly relies on archival materials and interviews supplemented in the final chapters by detailing the relatively nascent development of wind power in Taiwan. The remainder of this chapter explains the sources used and the structure of this dissertation.

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[49] See Kean Birch, "Materiality and sustainability transitions: integrating climate change in transport infrastructure in Ontario, Canada," *Prometheus* 34, no. 3-4 (2016): 191-206; Jochen Monstadt, "Conceptualizing the political ecology of urban infrastructures: Insights from technology and urban studies," *Environment and planning A* 41, no. 8 (2009): 1924-42.

[50] See Daniel K. Jonsson, "Situations of opportunity for infrasystems: Understanding and pursuing change towards environmental sustainability" (PhD thesis, KTH Architecture and the Built Environment, 2006).

1.5 Data collection

To contextualize Taiwan's energy history after the Second War, this project relies heavily on the TPC journals – the *Taiwan Power Company Li-Chin Monthly Journal* and *Monthly Journal of Taipower's Engineering.* These two journals have been the leading platforms for information exchange within the TPC since the 1940s. They are essential materials to show how the TPC engineers sometimes had different perspectives on the then-ongoing construction project or operational logic. As for the foreign consultative groups and their field trips to the construction sites, these transnational experts' visits and advisory reports, along with the TPC's official reports and publications regarding significant development plans, can be accessed from the Taiwan National Archive, Academia Historica, Taiwan Historica, National Central Library, the de Beausset Collections in the National Taiwan University Library, the National Archives Administration, and Archives of Institute of Modern History, Academia Sinica. I also have access to several TPC engineering reports and documents from a retired-TPC engineer's collection, Pin-yen Lin, stored in the Research Center for Humanities and Social Sciences in Academia Sinica.

Other sources showing how the TPC engineers received or learned about the up-to-date development of new energy technologies, power development in other countries, and potential partners for fuel procurements relate to those engineers' attendance at global energy conferences. Higher-ranking TPC engineers were often assigned to attend such conferences as representatives of the Republic of China and to report back any relevant insights. For example, the meetings held by the United Nations in Rome in 1961 on "New Sources of Energy and Energy Development" had significant implications in forging TPC's first self-manufactured wind turbine. Such materials could be collected in the digitalized catalog of the United Nations Archives and Records Management Section.

As for the documents for tracking offshore wind energy development in Taiwan, the government-funded preliminary studies on the feasibility of such new energy technology can be found in the Government Research Bulletin. At the local level, the negotiations and debates on its installation are well documented in the minutes of meetings of the Fishery Communication Platform, the local government's official statements, and records of Environmental Impact Assessment meetings held in the township office. In addition, I extracted news clips and magazine articles from the United Daily News Dataset and Kavalan Magazine to capture the demonstration scenes and narratives during the anti-Su-ao thermal power plant movement and other protests against TPC's nuclear power programs. Finally, to grasp the varied interests of multiple stakeholders regarding the construction of offshore wind power plants, I conducted interviews with the critical actors in the company leading the offshore wind project, Ørsted, and with government officials and fishery researchers who directed the negotiation platform between developers, regional fishermen associations, local and central government officials, and environmental NGOs.

My intention is not to document or contest different opinions among the stakeholders involved but to observe the process of compromise in which they tried to find common interests and possible solutions to change the equally controversial fishery management, ecological protection measures, and marine spatial planning. Therefore, I did not collect comments from individual fishers, representatives of the fishermen's association, or the environmental NGOs through interviews. Instead, I emphasize their negotiation results and the impacts of offshore wind energy development on the existing carbon-intensive network.

1.6 Chapter structure

In this dissertation, each following chapter is arranged to respond to a specific research question. Chapters are also interrelated as the TPC system gradually evolved into a carbon-intensive one by shifting its energy choices and interconnections with the different major consumers. Accordingly, the co-evolution of Taiwan's carbon-intensive power system and its corresponding network is explained chronologically and by different energy types. Chapter 2 examines the transition from hydropower to domestic coal and the introduction of imported fuels. Here, I explain the emerging tendency toward a carbon-intensive power supply-demand network by the late 1960s. I argue that instead of a self-explanatory account of energy scarcity either referring to domestic coal or (large-scale) hydropower that triggered past transitions, the varied visions of TPC engineers regarding the optimal energy mix show how their decisions were, in fact, focused on managing the accessibility of domestic coals with good quality and ensuring fuel flexibility of fuel oil and coal.

Chapter 3 describes how the generated system inertia determined TPC's energy choice to import hydrocarbon fuels and nuclear power even when encountering multiple challenges in the ensuing decades. Revisiting the turbulent years of the 1970s-80s, it becomes clear that Taiwan did not give up on oil when the first energy crisis hit in 1973. I differ with the conventional wisdom which says that the state's pursuit of energy diversification was due to the oil shock and became the main reason behind introducing nuclear power into the TPC system. As Chapter 3 investigates the two oil crises and the development of nuclear power in Taiwan, I argue that nuclear power had been lingering on the minds of policymakers and TPC engineers since the mid-1950s, simultaneous with the transition to imported oil. Furthermore, I proceed to point out that what brought serious setbacks to the carbon-intensive infrasystems was the ensuing protests against TPC's energy choice in the 1980s. I use the Anti-Su-ao thermal power plant movement as a case in point to argue that what forced TPC to divert its investments toward distributed units and alternative energy technologies was the growing doubts about TPC's authority in system planning in general, including the necessity of building the fourth nuclear power plant. Such public pressure and a new alliance between the DPP and grassroots movements should be seen as a collective response to the carbon-intensive network, which influenced TPC's further restructuring in the era of market liberalization in the late 1990s.

Chapter 4 takes readers to another development phase of the TPC system, characterized by a new set of actors accompanying the integration of distributed cogeneration units and renewable power units into the carbon-intensive network. While chapters 2 and 3 offer more comprehensive analysis to examine the historical formation and persistence of TPC's carbon-dependency through coupling with other infrastructure and industrial users, chapter 4 especially looks into Taiwan's wind power development to show how renewable energy technologies were materialized alongside the TPC system's evolution. In so doing, it also helps to reiterate the importance of a long-term and systemic understanding of energy transitions. Taiwan's wind power development today represents the endpoint of TPC's longstanding attempts to experiment with renewable energy technologies, dating back to the early 1950s. By tracing the journey of an engineer from TPC's maintenance factory to the UN's first international conference on alternative energy technologies in 1961, the side track of TPC engineers' efforts in building wind turbines on their own further illustrates how the specificities of time and place shaped the development of renewable energy. For instance, TPC's initial interest in harnessing wind power was to utilize it in a diesel-based power system on Penghu Island in case a declaration of emergency during wartime might leave military bases out of fuel and power. By the 2000s, however, the role of wind power in the TPC system had experienced a significant change.

I continue to develop another line of argument in chapter 4, which explains that for TPC, it was never about choosing between nuclear or renewable energy, as the latter remained at the system's margin regarding grid connection. The seeming rivalry between nuclear and renewable energy was rooted in Taiwan's democratization period, and the tension gradually peaked in Taiwan after the 2011 Fukushima Incident. The 2017 amendment of the Electricity Act symbolized the starting point for Taiwan's energy transition by demanding a substantial transformation in terms of market design, regulation, and TPC itself. However, the setbacks from the 2018 referendum's pro-nuclear result suggest the importance of stable policy support to keep up the pace of the transition. Outside the parliament, to understand what enlarging renewable generated electricity to 20 percent of the total generation in Taiwan entails for the local society and the existing carbon-intensive network, chapter 4 examines the obstacles and opportunities brought about by onshore and offshore wind projects. In turn, to prepare for the extensive wind penetration, the TPC system underwent several structural arrangements of the existing carbon-intensive network to accommodate such energy technologies, hinting that Taiwan's current renewable transition is more about continuity than a radical shift. The final chapter offers concluding reflections and wraps up with a summary and discusses the risk and vulnerability of Taiwan's carbon-intensive infrasystems, which could only be made visible by historicizing Taiwan's energy transitions.

Contextualizing energy transitions requires an integrating viewpoint that deals with both the path-dependence of the configured sociotechnical system and the varied political, economic, and social interests along the course of a changing energy mix. Instead of periodizing the shifts from hydropower to coal, oil, natural gas, and so on, my dissertation suggests contextualizing Taiwan's energy pasts through the lens of engineers and various historical actors. In so doing, we might be able to understand Taiwan’s complex energy politics and how “transitions” were considered and practiced for LTS like TPC’s and its partners’ in the carbon-intensive network. Before many energy options became available as Figure 1 suggested, for an island country left with a devastated power system after the Second World War, the next chapter begins with a group of rather ambitious engineers seeking solutions to bring the lights back to Free China.

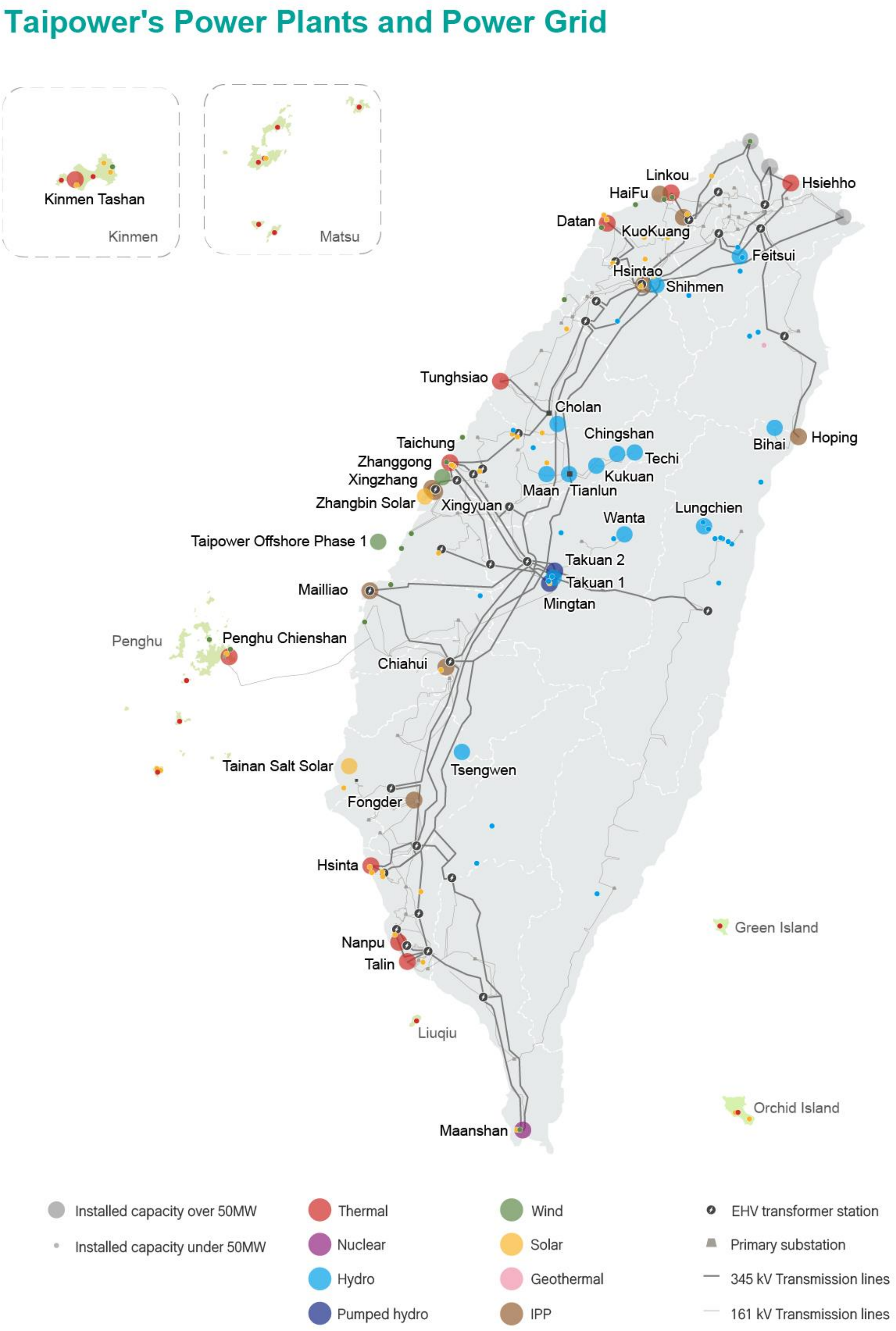

Figure 1 The geographical distribution of the TPC system in 2023.

Source: Extracted from TPC's website (taipower.com.tw).

Chapter 2: An Emerging Carbon Intensive Infrasystems in Early Postwar Taiwan (1945-1968)

2.1 Introduction

After reviewing the damages and remaining assets left by the Second World War, the still Nanjing-based Nationalist government released an electrification plan in 1947 that clearly stated their priority for restoring industrial power and which asserted that under current circumstances thermal power was considered ideal:

> If our country wants to be reborn, it must first develop the electrical industry in an all-around way as the driving force for all construction. The above-mentioned twelve power grids must be established in relatively affluent areas of the country. This plan's planned additional power generation capacity is more than 1,000,000 KW. Among them, thermal power accounts for about 5 KW. Generally speaking, although hydroelectric power is better than thermal power, thermal power is the principle of development for its shorter construction times.[51]

In this report, the areas of China formerly colonized by Japan (Taiwan and Northeast China) held the most promise for rapid restoration of productivity given the relatively developed heavy industries and power systems in both regions. Yet, unlike the already coal-intensive industrial ecology of Northeast China, with over half of the electricity generation fueled by coal, Taiwan’s electricity supply mainly depended on a hydropower capacity of 270,000 KW from 26 sites. Subsequently, the Nationalist government’s initial plan for Taiwan was to finish the construction of two hydropower plants at Wusheh (20,000 KW) and Tianlun (71,000 KW), while only the North thermal power plant (35,000 KW) was on the list to support the power usage of fertilizer and aluminum factories. As figure 2 shows, it was not until 1962 that the installed capacity and actual thermal power generation gradually exceeded hydropower.

What challenges stalled the pace of reconstruction, if thermal power was viewed as the best solution to the nation’s salvage? Shifting perspective from the planners in Nanjing to the engineers on the island, this chapter investigates the dynamic relations among different energy carriers within Taiwan's electricity mix and attempts to answer the question: What factors drove Taiwan's power system to gradually shift to thermal power? More specifically, how did domestic coal become the primary energy source? As imported fuel, especially heavy oil, started to eclipse the dominance of domestic coal in the late 1960s, how did the decision to shift again from coal to oil become possible?

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[51] NRC, 電氣事業 [The Electricity Business], (Nanjing City: Government Information Office, Executive Yuan, 1947).

Before Taiwan's first energy policy was formulated by the governmental agency Energy Development Planning Group in 1968, the process of deciding on an energy mix was more complex and diffuse. Section 2.2 depicts the historical continuity of the postwar power system with its colonial past. Placing the engineers' decisions regarding the "optimal energy mix" in a broader context of the state's industrial planning explains how the TPC system moved off the hydropower path toward an expansion of thermal power generating units since the 1950s. Switching over to domestic coal across the island, however, was not an easy task.

Section 2.3 examines how the power system was linked with transport systems to support that decision and ensure the new thermal power system's stable output. In section 2.4, I argue that instead of the possible exhaustion problem of domestic coal, what hindered TPC’s several attempts to control the uncertainty of domestic coal was the problem of gaining “accessibility.” On that basis, section 2.5 details how fuel oil became more desirable for the power system along with Taiwan’s booming oil economy. The birth of the “Taiwan District Energy Development Principle” in 1968 hints at a widely shared optimistic attitude toward oil and nuclear power in Taiwan and its gradually formed carbon-intensive infrasystems. In other words, what occurred during the late 1960s was not just about the choice for thermal over hydro, but also the lasting effects that choice had on the other systems.

In hindsight, such a decision – which entailed growing dependency on imported hydrocarbon fuels – may seem risky. By studying the changing electricity mix in early postwar Taiwan, this chapter argues that only by considering the concurrence of multiple transitions in terms of energy, transport system, industrial structure, political environment, and Taiwan's geopolitical position can we make sense of the TPC engineers’ past decisions. Moreover, in so doing, we are able to understand the origin of Taiwan’s carbon-intensive present.

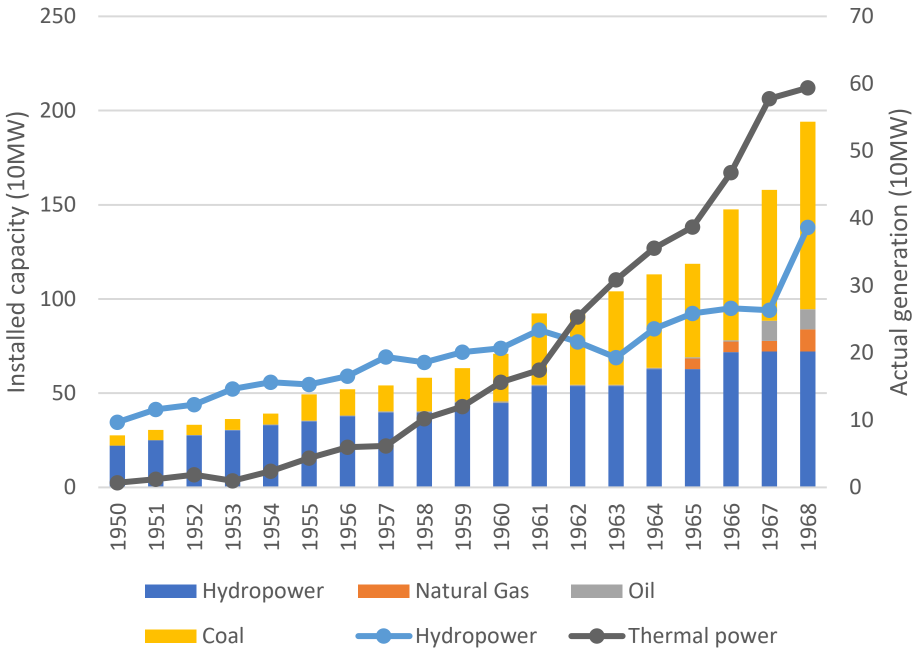

Figure 2 The installed capacity and actual generation by energy sources from 1950 to 1968.

Source: Data extracted from TPC's website (taipower.com.tw) and organized by author.

2.2 Rebuilding the TPC system on the roots of the Japanese colonial legacy and the party-state's planning economy

As Chapter 1 hinted, Taiwan's experiences of modernization and of heavy industries, including electricity generation and distribution, were transferred from the Japanese Empire. The early adopters of electricity were scattered across the island. They were primarily using it for small-scale lighting in hospitals, sugar refineries, lumber yards, streets, and governmental offices until the completion of the Sun Moon Lake power plant offered a massive and cross-regional electricity supply that boosted new markets.

With an eye toward expanding its colonies further south in East Asia through war, the Japanese Empire expanded, integrated, and utilized Taiwan's abundant electricity power supply. War as the catalyst of the power system's centralization could also be seen in Germany, Canada, the US, and Japan's main island around the same time. In Taiwan as in those other countries dams were the powerhouse of the war economy, given that features such as large-capacity generators, low electricity prices, and dependence on long-distance transmission lines enabled the state's intervention to direct power to support military industries.[52] During the 1930s-1940s, the Japanese Empire employed the Sun Moon Lake plant to support their aluminum and aviation fuel plants, which became the major electricity users in southern

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[52] Julie Cohn, Matthew Evenden, and Marc Landry, "Water powers: the Second World War and the mobilization of hydroelectricity in Canada, the United States, and Germany," *Journal of Global History* 15, no. 1 (2020): 123-47.

Taiwan under its grand "South Forward Policy." In order to exploit the heavy crude oil from Indonesia in 1942, the Japanese government built the Sixth Japanese Naval Fuel Plant and the required deep port facilities in Kaohsiung. In turn, the southern harbor city, which exported rice and sugar from Taiwan's south-central region to Japan, became Taiwan's power consumption center, accommodating the heavy chemical and other military industries.[53] Kaohsiung port city remained the essential node in Taiwan's transportation logistics and petroleum business after the Japanese repatriation, whose role in facilitating TPC's shift to imported fossil fuels will be discussed later in the following sections. In short, the Japanese colonial legacy laid the hydro-based foundation of the TPC system and left a port city with potential linkages with the established carbon-intensive users and networks.

After the Second World War, facing a power vacuum due to the unstable political situation in addition to a deficit of electricity generation, the Nationalist government launched numerous economic rehabilitation programs with the help of U.S. aid (1950-1965).[54] The outbreak of the Korean War triggered the relaunch of the U.S. aid program due to concerns about Taiwan's strategic position in the Asia-Pacific area in the 1950s. Taiwan's post-war reconstruction, therefore, shows how the "Asian Marshall Plan" promoted the U.S. government's political interests in sustaining opposition against the Communist Bloc in Asia.[55] Based on the partnership, the funds and technical assistance from U.S. aid played a

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[53] A series of insightful works on the Japanese colonial legacy of the 6th Naval Fuel Plant can see Chi-chuan Hsieh, "Japan’s national defense policy and military industry in Formosa during the colonial period – The development of 61st Naval Assembly Plant and the 6th Naval Refinery Plant" (PhD thesis, National Cheng Kung University, 2019); Shen-zhen Lin and Bing-yen Lin, "第六海軍燃料廠之接收," [The taking over of the Sixth Naval Fuel Plant.] *Kaohsiung Historiography* 6, no. 3 (2016): 60-99; Shen-zhen Lin, Bing-yen Lin, and Wan-xiang Huang, *第六海軍燃料廠探索：台灣石油/石化工業發展基礎* [Exploring the Sixth Navy Fuel Plant: The Origin of Taiwan's Oil/Petrochemical Industries' Development] (Chun-Hui Publish, 2013), 464; Yukikazu Takamoto, "The Research of Hsinchu branch of the Sixth Navy Fuel PlantDuring the Japanese Government" (Master thesis, Chung Yuan Christian University, 2014); Jen-shen Wu, "The actual power generation of ''Taipower'' power system during Japanese rule period (1920-1939)," *Journal of Humanities College of Liberal Arts National Chung Hsing University*, no. 39 (2007): 329-66.

[54] Taiwan received the US aid with its low interest loans since 1948 to 1965. There was a short-timed suspension between 1949 to 1950. According to the National Resource Commission’s representative in the US at the time, it was a difficult time to get loans from the US or Canadian companies considering the turbulence of war and their doubts regarding the national enterprises. See in Chen Yun, "美國對華態度及我國工業之出路," [The United States' attitude towards China and the developmental ways of our country's industry.] *Taiwan Power Company Li-Chin Monthly Journal* 1, no. 6 (1947): 2-3. The situation became even severe when the bilateral relation between the KMT-led Free China and the US went down in 1949. The State Department established the China White Paper 1949 (as known as United States Relations with China: With Special Reference to the Period 1944-1949) which condemned the Chiang Kai-shek’s government’s inability to control inflation, conspicuous ineptitude, and corruption among the higher leaders. See US Department of State, *The China White Paper: August 1949* (Stanford University Press, 1968), 1086. It was also the year when the first economic aid at 485 million dollars aids for an 18-month period beginning January 1, 1948 came to an end.

[55] Hiromi Mizuno, Aaron S. Moore, and John DiMoia, *Engineering Asia: Technology, Colonial Development, and the Cold War Order* (Bloomsbury Publishing, 2018), 272.

fundamental role in early postwar Taiwan's rebuilding of critical infrastructure.[56] In turn, the TPC system's evolution served different goals under the state's planned economy in the context of the Cold War.

Taiwan's power system was rebuilt on two premises. The first was the continuation of the Japanese engineers' efforts: hydropower, road, railway, port, water infrastructures, and unfinished plans. The other was the KMT's technical bureaucracy leadership in large-scale industrial planning in mainland China during the 1920s-30s.[57] The National Resource Commission was the primary governmental body organizing industrial development in the postwar period. In addition to the electricity business, the NRC oversaw the oil, iron and steel smelting, aluminum, ship manufacturing, machinery manufacturing, salt, cement, paper products, and sugar industries. Before the KMT government fled mainland China in 1949, the NRC drafted the post-war electricity development plan in 1943 for each region, putting rebuilding or developing electricity infrastructure among the heavy industry zones first. That principle guided the ensuing expansion of the TPC system.[58]

As described by the Assistant Director of the U.S.-aided industrial projects in 1955, NRC represented the Nationalist government's administrative ideology:

> …which has been taught to and practiced by a generation or more of Chinese Government leaders…at present and perhaps for the foreseeable future the potential industrialist is too inexperienced and not sufficiently concerned about the need of the economy and the people to develop the 'proper' type of industry, or in the rare instances when the proper combination of awareness and background is present, capital or management is lacking. Under such circumstances, the Government must step in and 'develop' industry.[59]

Following this principle, NRC appointed its members from the mainland, mostly trained engineers in different industries, as the president of the national enterprises, including the TPC.[60] This origin shows it was not a profit-oriented utility but operated under the nation's

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[56] After the end of US aid, the later initiated Sino-American Fund for Economic and Social Development and approved loans from the World Bank had then become the primary sources of TPC's power development in the 1960-70s.

[57] William C Kirby, "Continuity and change in modern China: Economic planning on the Mainland and on Taiwan, 1943-1958," *The Australian Journal of Chinese Affairs*, no. 24 (1990): 121-41; Limin Xue, Chen-kuo Hsu, and Dwight Heald Perkins, *Industrialization and the State: the Changing Role of the Taiwan Government in the Economy, 1945-1998* (Harvard University Press, 2001), 350.

[58] NRC conducted a report of the situations of electricity business and their plans for further expansion across the Nationalist China, including the mainland and Formosa, during and after the Second War. See also NRC, Short 電氣事業 [The Electricity Business].

[59] J. G. White "Industrial Development of Taiwan（Formosa）FY1952-FY1955" *Valery S. de Beausset Collection*, no. ntul_db07_02_001, National Taiwan University Library.

[60] By 1949, however, because several NRC's important figures turned toward the Chinese Communist Party, Taiwan's national enterprises became under the Taiwan Production Board (TPB) control. Example such as one of the NRC's vice-director, Yue-qi Sun, was appointed as the TPC's President in 1948 but

industrial plans. During the 1940s-50s, the KMT government was strongly aware of the immense importance of energy systems for economic growth.

It is not uncommon for a country's power systems to develop in parallel with the nation's rebuilding, but the actors involved in the subsequent system planning process vary due to historical contingencies.[61] Especially during the early post-war reconstruction period, the lack of foreign currency and energy sources (mostly coal) hindered many nations' industrial rehabilitation. In West Germany, multi-national companies, federal and state governments, transnational organizations, and industries (steel and chemical industries in particular) were actively engaged in making energy decisions.[62] As for Taiwan, its colonial past and the succeeding KMT's authoritarian regime led the country down a similar path to Bulgaria, Spain, and Greece. In order to save the expenditure on imported finished products and fuels with limited foreign reserves, the state exerted central control over the electricity business and developed its industrial plans to achieve autarky in terms of energy sources and political interests.[63] What deserves a closer examination are the practices that facilitated development. In Taiwan, the close relationship between the higher-ranking TPC engineers, managers in other state enterprises, and the leaders of government agencies set the foundation of Taiwan's carbon-intensive infrasystems: a fossil-fuel-based power supply and consumption system with subnetworks of fuel channels in which the power system and its users co-evolved.

Under the government's policy goal to restore the island's productivity, the TPC engineers' decisions regarding the location of power plants, priority in grid connection, price structure, and energy mix were planned along with the state's established four-year industrial development plans of 1953, 1957, 1961, and 1965 (Figure 3). It is clear that the installed capacity of thermal power generating units significantly exceeded hydropower's between

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turned to the People’s Republic China (PRC) the next year. Losing control over the mainland in the Civil War, the NRC’s influence on Taiwan’s industry was carried on by its members instead of the organization itself. See Chu, *台灣戰後經濟發展的源起: 後進發展的為何與如何 [The Causes of Taiwan's Postwar Economic Growth: The Why and How of Late Development]*.

[61] Bridge, Özkaynak, and Turhan, "Energy infrastructure and the fate of the nation: Introduction to special issue."; Wang Chih-ung and Huang Jo-tzu, "State-building as infrastructurization: The formation and transformation of Taiwan’s national development planning regime," *Journal of National Development Studies* 19, no. 1 (2019): 145-88.

[62] Boon, *Multinational Business and Transnational Regions: A Transnational Business History of Energy Transition in the Rhine Region, 1945-1973*. Also in cases of early 19th century Kyoto and the later integrated European power system, one can see the diverse groups that involved and how their interests shaped the formations of electricity systems. See Vincent Lagendijk, *Electrifying Europe: The Power of Europe in the Construction of Electricity*, Technology and European History Series, (Aksant Academic Publishers, 2008); Chen-xiao Xia, "Electrifying Kyoto: Business and politics in light and power, 1887–1915," *Enterprise & Society* 18, no. 4 (2017): 952-70.

[63] A special issue in the 127 volume of the Energy Policy Journal published a series of historical works enriching the understanding of energy dependence in cases of Europe’s nations. See especially Stathis Arapostathis and Yannis Fotopoulos, "Transnational energy flows, capacity building and Greece's quest for energy autarky, 1914–2010," *Energy policy* 127 (2019): 39-50; Lino Camprubí, "Whose self-sufficiency? Energy dependency in Spain from 1939," *Energy policy* 125 (2019): 227-34; Ivan Tchalakov and Tihomir Mitev, "Energy dependence behind the Iron Curtain: The Bulgarian experience," *Energy Policy* 126 (2019): 47-56.

1965 and 1968; however, the static data only reflects the final result and not the intermediate changes. The circumstances under which they turned to thermal power plants instead can only be answered by looking into TPC engineers' internal discussions and their interactions with government authorities and consultant agencies.

As the major recipient of U.S. aid funding, the TPC engineers worked closely with the J. G. White Engineering Corporation. In order to acquire financial support, the TPC engineers delivered general reports, statistics on electricity demand and supply by various sectors and generating types, and development agendas as requested. In return, the JGW engineers assessed their proposals' economic and technical feasibility and merits. Not just confined to a single electricity sector, the role the JGW played was also the bridge between different industries. They were invited to almost all the assessment meetings of the working groups initiated by the CUSA across various targeted industries and government agencies.

The TPC system did not solely operate based on the engineers' calculations and judgments. Instead, TPC's decisions were embedded in the broader picture of Taiwan's industrial development. Working with JGW and government agencies, TPC served the nation's purpose by setting up the most cost-effective power-generating units close to the industrial clusters. Hence, the government and consultant agencies' influence on their energy decisions were greater than the engineers perceived. Unsurprisingly, there were also contested visions regarding the definition of the "economic mix" of thermal and hydropower since the early 1950s.

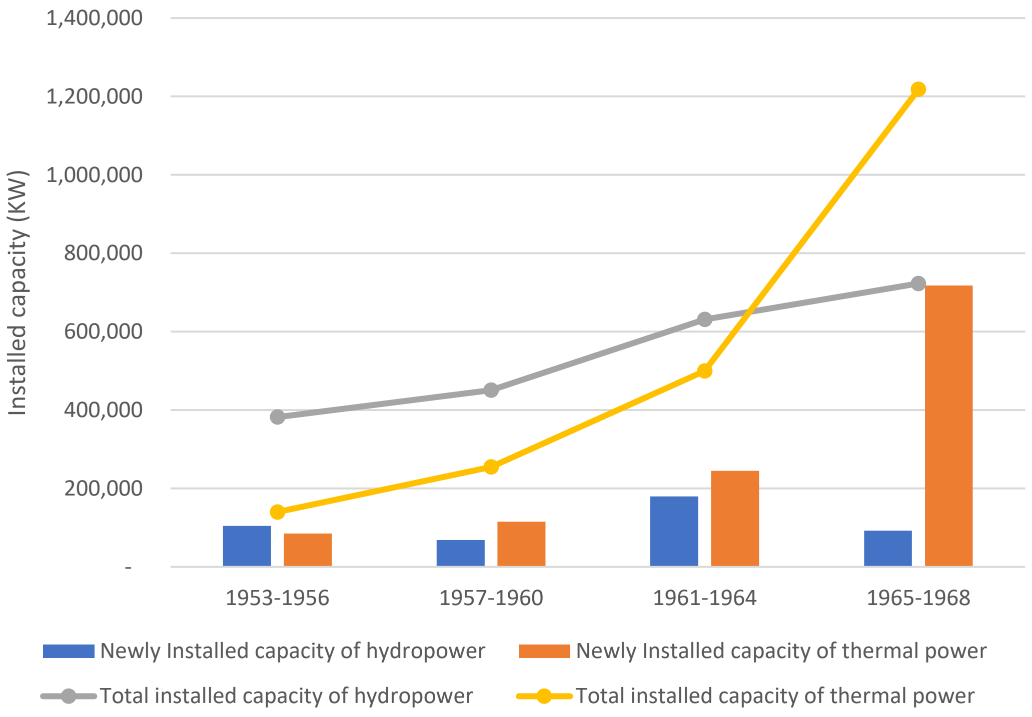

Figure 3 The variation of installed capacity of hydro- and thermal- power in the four development agendas.

Source: Numbers extracted from TPC's publication of *A History of Taiwan's Power Development: A Special Issue for the One Hundred Years Anniversary of Taiwan's Power Industry*.

2.3 Connecting the dots: the imbalanced regional load

Why and when did the TPC system consider placing more thermal power units with relatively higher fuel costs? As this section will explain, the growing imbalanced regional load was why the TPC system sought help from fossil fuels and changed the dominant role of hydropower; and the polarized consumption landscape that thermal power was meant to address had *already* begun taking shape in the Japanese ruling period.

After the erection of the Sun Moon Lake hydropower plant in the central region, the Japanese engineers had to form a sales team to sell the abundant electricity to the then-industrialized areas at port cities such as Keelung and Kaohsiung, situated furthest to the north and south of the island, respectively. Such a supply-driven development resulted in Taiwan's polarized regional loads.

Before 1945, there were only nine thermal power plants with a total installed capacity of 54,220 KW compared to twenty-four small- and large-scale hydropower stations of 266,915 KW.[64] The relatively more quickly installed steam generators powered by domestic coal or heavy oil fuel were installed at Keelung and Kaohsiung to supplement hydropower. Yet, domestic coal's higher price and uneven quality meant the steam generators operated only as auxiliary generators to cover the power shortage caused by the dry season or blackouts caused by typhoons or floods.[65] When the Sun Moon Lake power plant connected to the grid, the steam generators were then shut down and left aside because of their higher fuel cost.

This hydro-first operational logic was applied until the early 1950s: "unless the reservoir's water level was lower than the rule curve [and causes possible power shortage], the TPC would launch routine maintenance for fuel-fired generators during the rainy season. Until dry period, the generators would be started up then." This principle promised cheap electricity generated by the hydro baseload plants while also explain thermal power’s supplemental role in the TPC system considering its higher running cost in the early post-war period.

The weakness of a hydro-based power system, however, is that it is vulnerable to natural disasters and seasonal variations, as mentioned above. Once a disaster occurred, the long-distance transmission lines that the location-bounded hydropower plants relied upon would risk tripping and lead to rapid voltage drops among interconnected power-generating units.

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[64] TPC, *台灣電力發展史：台灣電業百週年紀念特刊* [A History of Taiwan's Power Development: A Special Issue for the One Hundred Years Anniversary of Taiwan's Power Industry] (TaiPower Public Relation Office, 1989), 911; CIECD, *臺灣電力開發運用美援成果檢討* [An Overview of the Utilization of US Aid in Taiwan's Power Development], 美援運用成果檢討, (Council for International Economic Cooperation and Development, 1964), 94.

[65] According to the Japanese’ surveys, the dry season was from October to February or March in the centra-southern area while the period started from December in northern Taiwan. See Wu, "The actual power generation of ''Taipower'' power system during Japanese rule period (1920-1939)."

Power rationing thus happened on a regular basis after the recovery of the TPC system in 1950. The targets of rationing were the intensive users such as aluminum and fertilizer manufacturing factories and others with a power purchase agreement over 500 KW. As industrial power significantly outraced household usage over time, eliminating rationing became an urgent matter (Figure 4).

Looking closer at the geographical distribution of industrial power, figure 5 shows that Keelung and Kaohsiung were the two major consumption centers. Among them, the chemical and metal manufacturing industries (including the aluminum and steel manufacturing factories) claimed the most significant share of the regional power usage, respectively. Finding solutions to meet the surge of power demand at extreme locations became the TPC engineer's priority task.

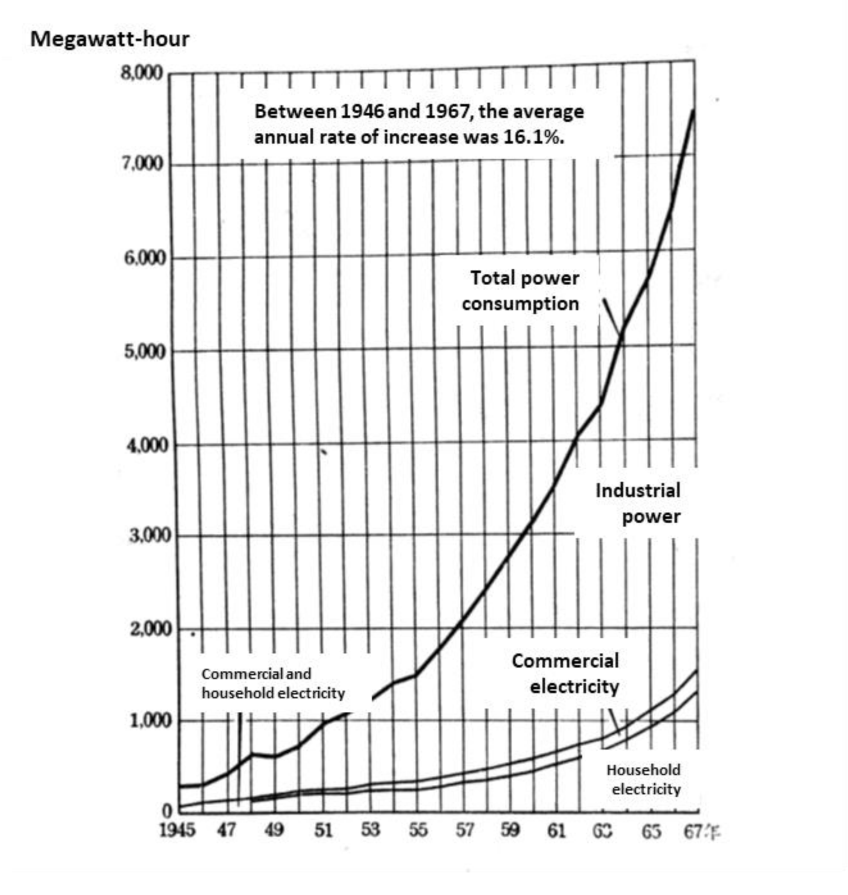

Figure 4 The TPC electricity sales by sectors during 1945-1967.

The accumulated line refers to total electricity sales, including industrial, commercial, and household usage.

Source: Extract from Jia-yu Yang’s paper on Taiwan’s electricity system in 1964, "臺灣電力之建設與經營.” [Construction and operation of Taiwan's electricity system]. [In Chinese]. *Quarterly Journal of Bank of Taiwan* 15, no. 2 (1964): 43-73.

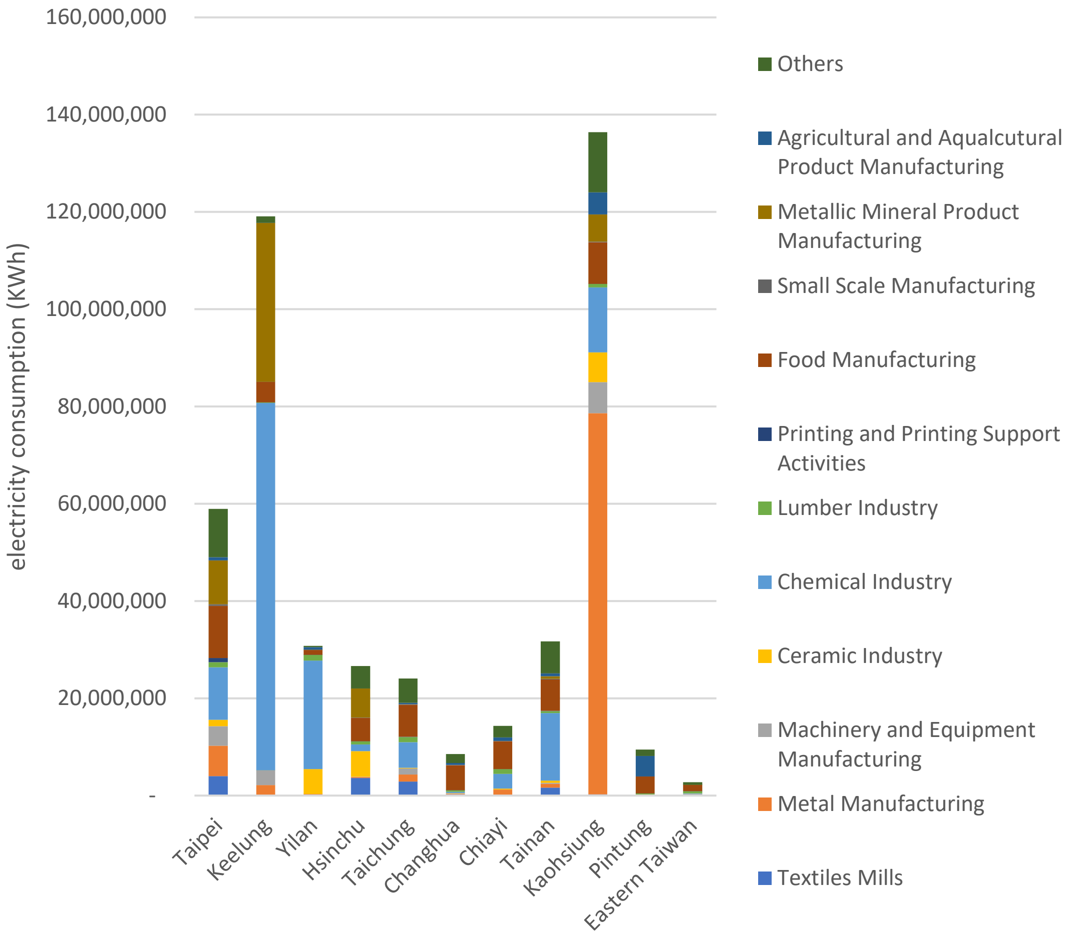

Figure 5 The industrial power consumption in 1950 (excluding the outlying island city, Penghu, due to its independent power system).

Source: Remade from an original paper in 1952 titled “Taiwan’s electricity and industry” by Chu Chiang-huai and Lu Yan-di.

In response to the task, one of the important hydraulic engineers and managerial figures in the TPC, Chu Shu-Lin, suggested utilizing the river resources on the island by building the corresponding scales of hydropower plants to supply the industrial needs.[66] His opinion matters to this research because he was ranked at Deputy Engineer and just transferred to TPC’s Planning Department in the early 1950 and thus, offers a different view within the major decision-making group.[67]

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[66] Chu served as the TPC’s vice-president and department director in charge of power development during 1963-1976, and later president in 1976. His observations offered this present study a valuable source to probe the idea changes behind TPC’s energy decisions over time. His opinion on the ideal power grid can see Shu-lin Chu, "臺灣之電源 [Taiwan's power resources]," [Taiwan's power resources.] *A Quarterly Journal of Taiwan Bank* 5, no. 1 (1952): 25-64.

[67] "人事動態月報表；職員調查表 [Monthy report of the changed employments; employee survey form]" *National Resources Committee*, Academia Historica Collection, no. 24-11-10-002-01, Academia Historica.

Chu's picture of an ideal grid was to utilize all possible hydraulic power resources across the island, especially by integrating with the regional harbors as the co-located nodes of the power grid and heavy or chemical industries. In so doing, first, the location might benefit the TPC by reducing the transport cost of imported crude oil in the future. Second, prioritizing the connection to the nearby intensive state-owned electricity consumers such as aluminum or ammonium sulfate factories could help the TPC system better control load variations.[68] For example, they could instruct the factories to operate only in off-peak hours during nights or holidays; because of the state's control of both the TPC and the factories, such instructions *seemed* likely to be followed.

Therefore, based on that premise, except for cities such as Keelung and Kaohsiung, building new thermal power plants was thought unnecessary. The cheaper and abundant hydroelectricity nearby or reachable through high-voltage transmission lines, which were planned to be set from 140KV to 150KV, was thought to be more economically feasible for running the TPC system. As figure 6 shows, Chu's blueprint envisioned the hydropower based-system integration with rivers, ports, and industrial clusters, while the Sun Moon Lake would remain the major mediator and coordinate with other run-of-rivers power plants to meet the baseload power (the minimum level of demand on the grid).

Chu was trying to remind his colleagues that the economic benefits of applying different turbines to exploit hydropower in regions could help stabilize the power supply while also creating a more balanced regional load. In fact, there were suggestions to install small-scale and low-head hydropower generators at the rivers with lower than 50 meters of vertical height between the intake and turbine in the early 1950s, but as TPC's director of hydropower engineering tasks, Chiu Hsieh-chun, explained, this way might only burden TPC's task to ensure stable power during dry seasons.[69] Chu's ideal vision was then shelved, but the reasons behind the shelving could offer more clues about the changing position of hydropower plants in the TPC system and TPC's growing preference for domestic coal in the mid-1950s.

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[68] See Sao-yang Hong, "Transformation between military need and civilian demand: Establishment of Ammonium Sulfate factory in pre- and post-war Taiwan," *Taiwan Historical Research* 25, no. 3 (2018): 141-78. The paper had a detailed discussion on the early development of Taiwan's fertilizer industry. The ammonium sulfate factories were once for military used to produce gunpowder in Kaohsiung.

[69] Hsieh-chun Chiu, "臺灣的水力," [Taiwan's hydropower.] *Monthly Journal of Taipower's Engineering*, no. 43 (1952): 5-10.

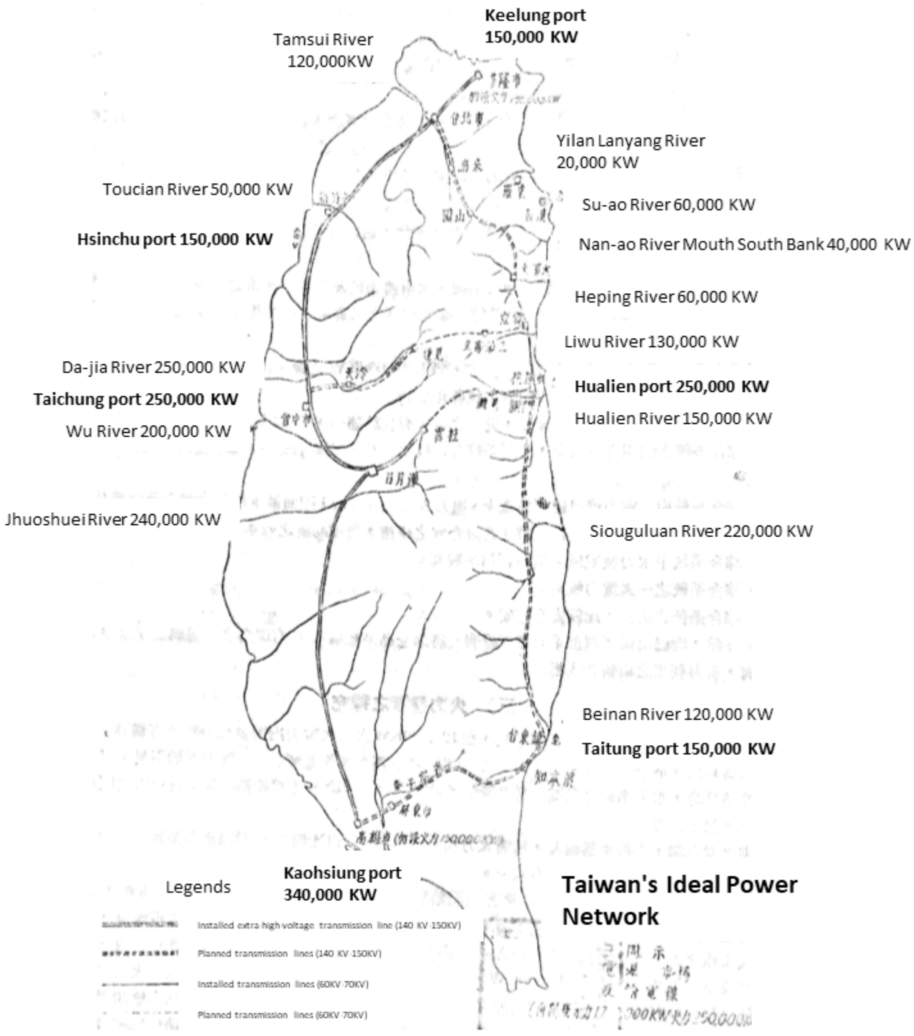

Figure 6 A schematic diagram of the ideal power grid drawn by Chu Shu-Lin in 1952.

The power lines to be built were indicated as dotted lines and the potential installed capacity of each river in the east and west areas were also addressed along the side of the names.

Sources: Excerpted from Shu-lin Chu, "臺灣之電源 [Taiwan's Power Resources]," [Taiwan's Power Resources.] A Quarterly Journal of Taiwan Bank 5, no. 1 (1952).

First, electrification did not reach as broadly in the eastern part of Taiwan as in the western region.[70] The 66KV double-circuit East-West transmission line was installed in 1953 not to boost economic development at the eastern ports but to exploit the electricity generation in this less populated area. TPC's planning logic was based on load-following that prioritized the expansion of baseload power plants to ensure power stability in the polarized load centers. The relatively location-bounded hydropower plants were, thus, not competitive in this regard

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[70] Li Rui-zong was able to access piles of documents and reports in the TPC's storage house to write a book on the history of the hydropower system in eastern Taiwan under TPC's cultural heritage preservation programs. See Rui-zong Li, *後山電火：東部水力發電 [Lighting across the Mountains: Taiwan Eastern Hydroelectric Power Plants]*, Taiwan Power Cultural Heritage Book Series, (Taiwan Power Company, 2019), 248.

with the thermal power units. To further this point in terms of the construction cost, building a thermal power plant was cheaper and quicker than hydropower because the required equipment could be procured by foreign loans. As mentioned earlier, from 1951 to 1964, 62 percent of the total U.S. aid funds went to the TPC system's expansion project. The TPC utilized investments in centralized and capital-intensive projects ranging from the Wusheh concrete dam to the larger-scale steam generating units and the cross-regional high-voltage transmission lines.

Expanding thermal power generating units takes considerably shorter construction time than building dams. While the task of repairing run-of-rivers and impoundment hydropower plants was underway throughout the 1950s to 1960s, installing more coal-fired steam generators became even more favorable to the TPC managers given the availability (and conditions) of U.S. aid. Even hydraulic engineers like Chu compromised with such a trend because the TPC's budget greatly relied on foreign loans. For instance, Chu and the CUSA's vice director went to the U.S. Department of State to negotiate a 40 million USD loan for their planned Tachien Dam's construction in 1963. It was issued, however, under the condition that 33 million should be allocated to the Linkou thermal power plant, leaving only 7 million for the planned first phase of the Tachien project.[71] The completed Qingshan hydropower plant was also the last TPC project using the funding.

Therefore, even if Taiwan's coal mines were mostly located in the northern area, and the higher transportation cost made the fuel cost claim over 60 percent of the total power generating cost, it did not cease the subsequent planned construction of the coal-fired Nanpu power plant in Kaohsiung to feed the nearby industrial cluster. Still, this decision was not a sound solution to fixing the power shortage, at least according to some of TPC’s hydraulic engineers. The TPC in-house journal discussed fears that the expensive fuel cost might deviate from the economic principle, employed since the early 1950s, of the optimal coordination between hydro and thermal power. The TPC managers, however, turned their attention to coal-fired steam generators.

How exactly did hydropower plants gradually lose their dominant position to domestic coal since the mid-1950s? One can glean some clues from the distinctive lessons TPC engineers took from the Tennessee Valley Authority (TVA) model and applied in their development plans for the Dajia River. TVA’s experience in regional planning with multi-functional dams was widely discussed then. The international programs with the TVA aimed to optimize the river resource and infrastructural investment.[72] Meanwhile, they represented another aspect of

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[71] De-pei Yu and Qiong-rou Lin, *台灣電源開發史: 口述史* [Taiwan's Power Development: An Oral History] (Taiwan Research Institute, 1997).

[72] The international programs with the TVA were aimed at optimizing the river resource and infrastructural investment. They represented another aspect of the common experiences in the East Asia in terms of cross-regional knowledge exchanging and personnel training. Through the following technical exchange projects, the transnational experts’ network continually shaped the nations’ natural,

the common experiences in East Asia in terms of cross-regional knowledge exchange and personnel training. As the Japanese electrical engineers observed at the 9th World Power Conference, since the mid-1950s, developing multiple-purpose dams based on the TVA model, enlarging the installed capacity of steam generators, building nuclear power plants, and systematization were the major concerns in Southeast Asia.[73] Usually, what engineers or policy makers learned from TVA was about dams, but here it was not just multipurpose river development, but multi-source energy-generation systems.

TPC engineers not only participated in those conferences but also paid visits to the United States Bureau of Reclamation and the TVA to bring back knowledge about taming the river via multiple-purpose dams and the electricity transmission system. Aside from appropriating the TVA elements in TPC's Daja river power plants, TPC engineers saw another of TVA's important attributes: the TVA's system subsequent expansion via completion of different hydro, thermal, and nuclear power plants in Tennessee. Especially the installed pump turbine in TVA's Hiwassee Dam, also the world's first pump-storage unit, significantly changed TPC engineers' expectations toward hydropower plants. Chu wrote an article in 1956, *The Future Trend in Hydropower Engineering*, to address this idea of harnessing cheap power from the pump-storage unit and utilizing its capability of faster start-up and storage function to help balance the loads with large-scale thermal and nuclear power plants.[74] Although the idea clearly differed from Chu's blueprint of 1952, Chu was rather enthusiastic that it might also give the costly hydropower plants new roles to play in Taiwan's energy future with nuclear power.

Chu's attitude suggests a fundamental shift in TPC's expansion mode: its long-range power development plan was no longer based on a single power-source but rather on the coordination among hydro, thermal, and nuclear power plants. In other words, TPC had already embraced the idea of energy diversification in the mid-1950s, especially with the coming age of civilian nuclear programs. The idea of applying the TVA model to build Taiwan's highest Tachien Dam (now called the Techi Reservoir) at the head of a watershed in the upper reaches of the Dajia river for flood control, irrigation, and power generation in 1955 further stresses this point.[75] When Chu Chiang-huai, then TPC's assistant manager, reported to the

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political, and social landscapes. See Vincent Lagendijk, "Streams of knowledge: River development knowledge and the TVA on the river Mekong," *History and Technology* 35, no. 3 (2019): 316-37.

[73] Tomita Kohei and Matsuda Tai, "東南アジアの電力開発," [The development of electricity in the Southeast Asia.] *The Journal of the Institute of Electrical Engineers of Japan* 84, no. 907 (1964): 524-33, https://doi.org/10.11526/ieejjournal1888.84.524.

[74] Shu-lin Chu, "水力發電工程之趨勢," [The future trend of hydropower engineering.] *Monthly Journal of Taipower' s Engineering*, no. 98 (1956): 1-13.

[75] Initially, the plan was stemmed from an appeal drafted by 14 Provincial councilors representing the central area. In response, the Provincial government established a planning committee, which convened by Sun Yun-suan to arrange the construction details and budgets with nine relevant government agencies. After 20-year construction of the dams, the Taichung port, and the waterfront industrial zone, harnessing the Dajia River represents a very rare bottom-up engineering task and the result is a major

promotion committee in 1957 about the general plan, he especially quoted the advice of André Coyns, the invited French expert on arch dams:

> *In the past, hydropower was the primary source in the world, but now, after the invention of the atom, thermal power will be the primary power source… Although there is an abundant water source in Tachien Dam, it is better to design and use hydropower as a secondary source in meeting the power demand in this era of atomic power.*[76]

Taiwan’s Atom Energy Research Committee (now known as the Atomic Energy Council, AEC) was established in the same year the multi-functional Dajia River plan was implemented. In André Coyns’ other article about TPC's planned multiple-purpose dams and the power plants along the Dajia River in central Taiwan, Coyne specifically emphasized that they should function as peak-load plants instead of large-capacity baseload plants.[77] In short, from the TPC's perspective, what they saw in the transferred TVA experience was not only from the aspect of dams-centered regional planning but also the potential for the system's further expansion with other sources of energy. The comprehensive planning signaled a fundamental change in TPC's expansion logic, which enabled the subsequent expansion of thermal power plants at the consumption poles.

Facing the imbalanced regional loads, the TPC system did not evolve toward a distributed system regarding spatial expansion but density. That is, instead of mitigating the disparity in regional usage, TPC rather focused on the centralized consumption poles in the north and south areas with the help of the U.S. aid funds, which resulted in TPC's increasing dependency on fossil fuels with more steam generators joining the system. The completion of the Nanpu thermal power plant in 1955 represents the beginning of the TPC system's further dependency on fossil fuels – domestic coal at first. In order to detail how domestic coal was deployed in the initial phase, the following section looks into the development of the Nanpu power plant at Kaohsiung port despite its disadvantage of the higher transport cost of domestic coal. The discussion will show how the materiality of domestic coal made the TPC system further integrated with infrasystems such as ports and railways. Moreover, the corresponding development of Kaohsiung port exemplifies how the TPC system adapted to the integration with the gathered intensive electricity users at the port hinterland and vice versa.

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leap forward of the economic development of Taiwan’s central region. A more thorough review on the Japanese legacy and the materialization of the Dajia river development plan, see Rui-zong Li, *大甲溪：水電俱樂部* [Da-Jia River: Hydroelectric Power Plants], Taiwan Power Cultural Heritage Book Series, (Taiwan Power Company, 2018), 295.

[76] Shou-shu Qin, ed., *促成大甲溪主要資源開發輯要 [Editorial Summary of Promoting the Development of Main Resources of Dajia River]* (Dajia River Comprehensive Development Promotion Committee, 1973), Pages.

[77] André Coyne, "大甲溪中游電力開發," [Electric power development in the middle reaches of Dajia River.] *Monthly Journal of Taipower’s Engineering*, no. 113 (1958): 1-11.

2.4 Growing in density: linking up the thermal power plants and heavy industries in Kaohsiung port-city in the mid-1950s.

I define the densified expansion of the TPC system based on two aspects. First, it refers to the TPC's growing installed capacity of coal-fired steam generators, coal storage facilities, and higher-voltage distribution lines at the port's industrial cluster. That is, the escalated scale of the thermal power system does not stop with the setup of a single power plant. The TPC engineers had envisioned the possibility of subsequent add-ins by leaving spaces in their original plant designs. From the first Four-Year Development Plan onward, the Nanpu power plant installed three generating units with a total capacity of 205,000 KW. The third unit's capacity was even enlarged significantly to 125,000 KW. To reduce the transmission loss, the voltage of transmission lines that connected the Nanpu power plant to the factories in Kaohsiung was increased to 66KV in 1956. With the proliferation of direct current lines in certain areas, the TPC system substantially grew in terms of the increasing amount of carried loads and the corresponding installed capacity of power units.

Another aspect of densification is in the form of coupled infrasystems. Building a thermal power plant in Kaohsiung meant the TPC would have to rely on the Taiwan Railways Administration's (TRA) arrangements to extend the port-route sidings and deploy more coal hopper cars to carry the domestic coal from Northern Taiwan. Infrasystems such as railways and harbor facilities were, therefore, extended and multiplied in the same area. For instance, as I will later discuss, Kaohsiung port underwent a 12-year extension program in 1956 and was surrounded by Taiwan's largest-scale urban circular railway because of its various sidings that penetrated the industrial zone. As for the Kaohsiung Station, it already handled mixed freight, including the biggest item such as cement, rice, and fertilizer, with a volume exceeding 50,000 tons yearly – the largest single station volume in Taiwan in the mid-1950s. Simultaneously, the TRA began to mechanize material handling equipment.[78] Together, these coordinated electricity and fuel transportation networks enabled the TPC to deploy domestic coal, and import fuel (oil starting in 1965, coal in 1969, and liquefied natural gas in 1990) into Kaohsiung in the following decades. The formation of such a carbon dependency begins with problems involved in that switch relating to the deployment of domestic coal.

2.4.1 The uncertainty of domestic coal

The island's geological age is relatively young, with thin coal seams dating to the Miocene. Domestic coal was mainly comprised of bituminous and sub-bituminous coals, known as the common types of steam coal (or thermal coal), which are unevenly distributed in the Lower, Middle, and Upper layers in the northern region (see Figure 7). When the domestic market for

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[78] TRA "1955 年度鐵路計畫 [1955 Railway Plan]" *行政院經濟建設委員會 [Council for Economic Planning and Development]*, Academia Historica Collection, no. 0400104020001, Academia Historica.

coal was in its infancy, Taiwan's coal industry had been a regional part of the world economy, with its export market in Southern China, Hong Kong, and the Southeast Asian colonies of Great Britain and France under the Japanese administration's monopoly on purchase and marketing in the late 19th century.[79] The prosperous coal business had further led the port city of Jilong (former Keelung) at the northern pole of Taiwan to undergo a series of urban planning projects and infrastructure improvements through the coordination between the Japanese settlers and Taiwanese elites. While the Japanese exerted strict control over mining rights through licensing, Yen Yun-nian (1874-1923), whose family had been mining and farming in the Ruifang region of Jilong, was the first Taiwanese to get access to the open mines.[80] Subsequently, the Yen brothers, Yen Yun-nian and Yen Guo-nian (1886-1937), worked closely with their Japanese partners to put down their family business' roots in the coal mining industry.

As they kept applying for new coal mines, they also established solid connections across the mining companies that were able to establish the Taiwan Mining Association in the 1910s, constituted by Taiwanese and Japanese leaders in the industry. Yen Yun-nian was even titled the "Coal King" in respect of his position in the coal business network and the number of coal mines under his family's name.[81] Their success also resulted from their vision of investing in the construction of railways and sidelines for transporting miners, facilities, and coal from/to dispersed mines. The Yen brothers and Kimura Kutaro (1867-1936), another leader in the mining business, co-founded Jilong (Keelung) Light Rail Corporation which helped the production and delivery capacity of Yen's mines surpass other competitors. In so doing, even after the First World War, when the skyrocketing demand for coal brought the Japanese Zaibatsu, including Mitsui & Co., Mitsubishi Group, and Kuhara Zaibatsu, into the northern coal market, the Yen brothers still managed to operate their coal mining business as a major shareholder in the Zaibatusu-owned Jilong Coal Mining Corporation. Alongside the investment, in 1920, Yen Yun-nian integrated over 50 affiliated family businesses into the Taiyang Mining Co., marking a generation's effort in mining, transporting, and selling domestic coal in the Japanese ruling period.

Before the Pacific War broke out and the Japanese government brought the coal industry under state control through the newly founded Taiwan Coal Company to meet the military

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[79] Tsu-yu Chen, "The Development of the Coal Mining Industry in Taiwan during the Japanese Colonial Occupation, 1895–1945," in *Studies in the Economic History of the Pacific Rim* (Routledge, 2002), 195-210.

[80] I-fang Yen, "基隆顏家與臺灣礦業開發," [Shoulder the heavy responsibility of mining development in Taiwan's Keelung Yen family.] *Taiwan Historica* 62, no. 4 (2011): 105-30.

[81] In his recent book on the formation of Taiwanese awareness, Evan N. Dawley explicitly portrait the various attempts of boundary making/succeeding of identities along with the evolution of Keelung City from the Japanese ruling period to the early Nationalist Taiwan. Taiwanese elites especially actively engaged in the process, as Dawley insightfully pointed out, in which the Yen family occupied a significant part of the story. See Evan N. Dawley, *Becoming Taiwanese: Ethnogenesis in a Colonial City, 1880s-1950s* (Brill, 2020), 413.

needs at the frontline, domestic coal was mainly sold to the sugar processing plants in southern Taiwan. Other domestic coals mainly went to the usages of coal steamers and export (Figure 8). With the Yan family's strong local coal industry network and business skills, even after the Nationalists proclaimed the seizure of all Japanese assets once the war ended, including the Taiwan Coal Company, they remained influential in Taiwan’s coal business.[82]

Yen Chin-hsien (1912-1983), the son of Yen Guo-nian, bought back the Taiyang Mining Co. from the Provincial Government and engaged actively in organizing coal mining organizations in postwar Taiwan. For example, Yen led his fellow coal mine owners to organize the Taiwan Provincial Coal Transportation Cooperative in August 1946 when the Provincial Government lifted the coal control system. Although the ensuing Civil War had once again put domestic coal under rationing by the Provincial Coal Control Commission (PCCC), Yen still had channels to ensure their opinions would be heard in the government, as I will discuss further, when the “coal problem” became severe after liberating the coal market in 1954. The Yen family and other Taiwanese coal mine operators’ endeavors in laying their connections through business, political, and railway networks had built a thriving port city based on domestic coal in northern Taiwan, despite their unequal positions relative to the colonizer and the mainlanders.[83]

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[82] Since Jilong Coal Mining Corporation, Jilong Light Rail Corporation, and the Taiwan Coal Mining Corporation were in joint venture or directly enlisted under the Japanese Zaibatus, these assets were taken over by the Provincial Government-owned Taiwan Coal Mine Development Corporation. See Taiwan Industrial Development Corporation, *臺灣工礦股份有限公司創立實錄 [Records of the founding of Taiwan Industrial Development Corporation]* (National Central Library, 1947), https://tm.ncl.edu.tw/.

[83] It is worth noting that in addition to the Yen family, there were also other prominent local figures in Taiwan’s coal industry such as the Li family owned Ruisan Coal Mining Corporation since 1934. These Taiwanese elites often would hold positions in the City or Provincial Council to protect their business interests, which could also explain their long-lasted influence even within political regime changes. For instance, their backgrounds distinctively differ from those government agents, such as the geologists or managers sent from the NRC, as they often start their careers either from being a miner, bookkeeper, or other entry-level employees themselves. Yet, when the NRC director-founded Chinese Institute of Mining and Metallurgical Engineers relocated to Taiwan in 1952, Yen Chin-hsien and the Li brothers, were the first of others to apply for spontaneous sponsorship to the society to establish communication channels and connections with them. Chinese Institute of Mining and Metallurgical Engineers, 中國鑛冶工程學會會史之三(96 年增修版) [History of the Chinese Society of Mining and Metallurgical Engineering Part Three (Additional Edition in 2007)], 2007, Chinese Institute of Mining and Metallurgical Engineers

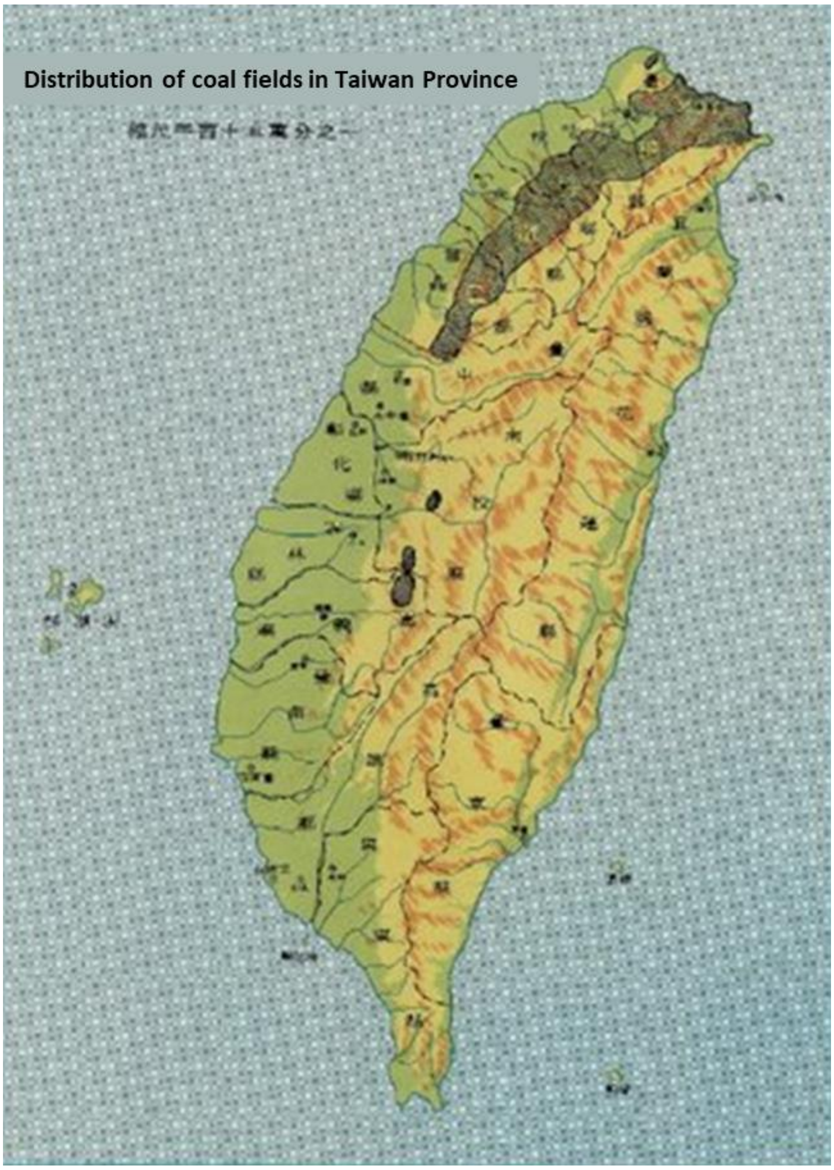

Figure 7 Black areas suggest the locations of Taiwan's coal fields in the 1960s.

Source: Excerpted from "臺灣煤業之輔導與調節 [Counseling and adjustment for Taiwan Coal industry]," in 臺灣省政府委員會議 [*Taiwan Provincial Government Committee Meeting*] (00501102411, Taiwan Historica: Taiwan Historica Collection, 1969).

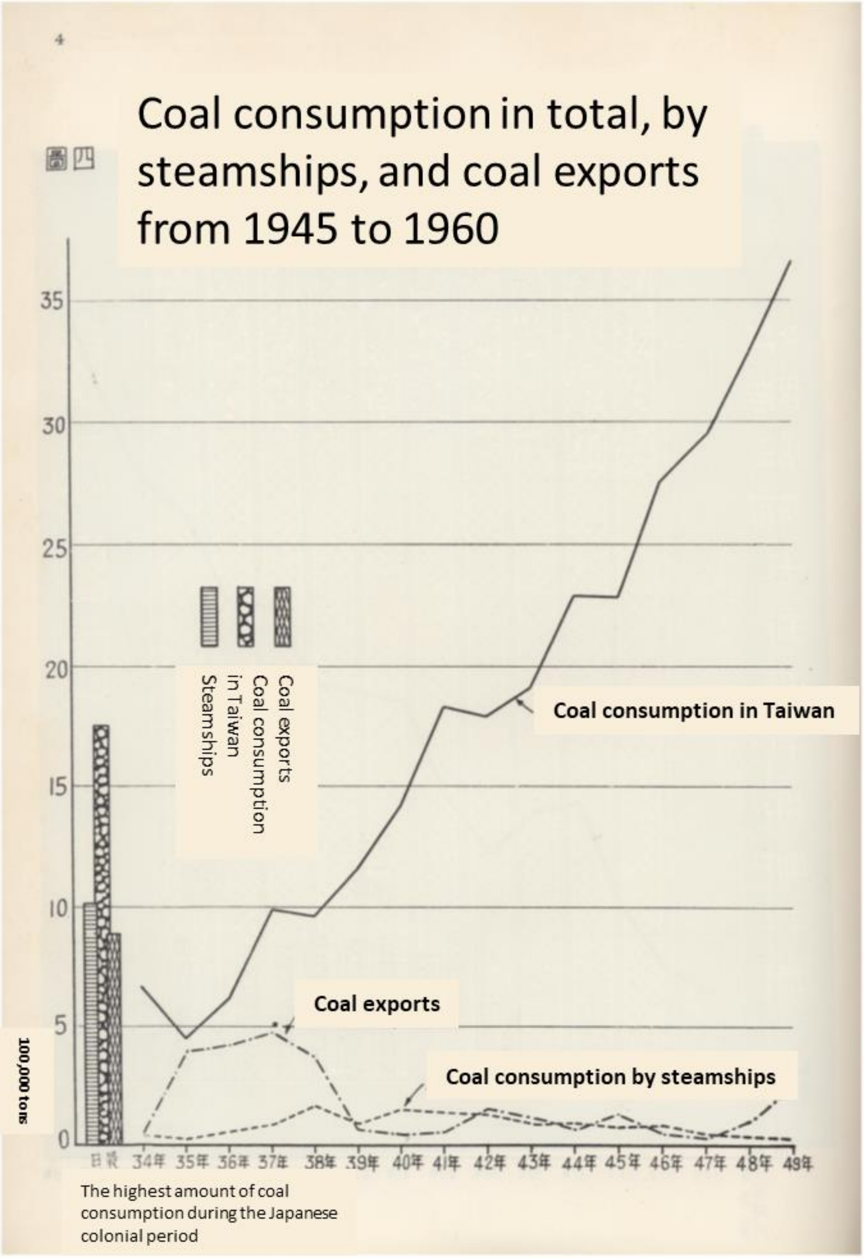

Figure 8 The selling amount of domestic coal to coal steamers (indicated by the bar with horizontal stripes and dotted line), domestic uses (the bar with reticulated shape and the solid line), and exportation (the bar with grids and the dashed-dotted line) during the Japanese ruling period and afterward to 1960. The bars suggest the sales former.

Source: Excerpted from "臺灣省煤業調節委員會重要工作檢討報告 [Review report on important work of the Taiwan Provincial Coal Control Commission]," in *臺灣工礦股份有限公司 [Taiwan Industrial Development Corporation]* (016-00372, Taiwan Historica: Taiwan Historica, 1960-1961).

With the end of the Chinese Civil War, Taiwan's coal industry lost its primary export market on the mainland. The accumulated coal stockpile reached 200,000 metric tons (m/t) in 1951, which led to the PCCC's intervention in price control. The cuts in price decreased coal production to less than 100,000 m/t per month in return, while the domestic demand for coal was about 130,000 m/t per month. Such regulation caused the Cement Plant at Kaohsiung and two Taiwan Fertilizer Company plants to curtail operations due to the lack of coal between the end of 1951 and early 1952.[84] They pressured the supervising authority of national enterprises, TPB, to react to the shortage. At the same time, the JGW surveyed the coal mining equipment and urged the TPB and Department of Reconstruction (DOR, Taiwan Provincial Government) to improve the worn-out physical plant (given that most coal mines had no capital with which to do maintenance). The PCCC then implemented production bonuses and price increases as incentives to production, resulting in too much coal again. K. Y. Yin, the influential statesman and the convenor of the TPB (renamed ESB then), held a series of meetings to deal with the vicious circle.[85]

When the TPC pinned the Nanpu power plant on the list of its first Four-Year Development Plan (1953-1956), it found itself at the tipping point of the market reform of the coal industry. The debate between the government agencies, Taiwan Coal Mining Association, JGW, and national enterprises went on for the whole of 1953 over whether to decontrol coal.[86] For example, from the coal mine owners' perspective, Yen Chin-hsien as the representative of the Taiwan Coal Mining Association, wrote to the TPB in 1950 to demand the continuation of the coal control system. Since over half of Taiwan's coal mines were small-scale ones with a monthly production capacity under 500 metric tons, their output significantly relied on national support with a thorough production plan, unified market price, loans for equipment improvement, coal transportation, coal quality standardization, and a certain volume of coal stockpile inventory.[87] However, the resolution of deregulation came out in 1954 with the replacement of the PCCC by the Provincial Coal Adjustment Committee (PCAC). PCAC carried four major goals: production improvement, supply-demand adjustment, coal price stabilization, and export promotion. It became the main negotiator between the coal mines and the national enterprises by keeping a certain volume of coal stockpiles for adjustment

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[84] The management problem of Taiwan's coal market was addressed in a letter wrote by a Senior Mining Engineer of JGW to its project manager, de Beausset, in 1953. See Phillip. C. Emrath "A memorandum of coal industry resume" *行政院經濟建設委員會 [Council for Economic Planning and Development]*, Academia Historica Collection, no. 0400104090017, Academia Historica.

[85] The TPB members yielded significant influence on Taiwan's economic and industrial policy in the 1950s-60s. See Xue, Hsu, and Perkins, *Industrialization and the State: the Changing Role of the Taiwan Government in the Economy, 1945-1998*. Its influence was succeeded by K. Y. Yin-led ESB in 1953. In the same year, Yin created the Industrial Development Council (IDC), which subordinated to the ESB became Taiwan's first government agency of industrial planning. Another important figure in Taiwan's economic policy, K. T. Li, was invited by Yin as the IDC member. Throughout the 1950s to 1960s, Yin and Li used the institutions and connections to channel resources from U.S. aid to targeted industries and the S&T policy. See Chu, *台灣戰後經濟發展的源起: 後進發展的為何與如何 [The Causes of Taiwan's Postwar Economic Growth: The Why and How of Late Development]*.

[86] "礦業：煤礦管制 [Mining Industry: Coal Mining Regulation]" *行政院經濟建設委員會 [Council for Economic Planning and Development]*, Academia Historica Collection, no. 0400104090017, Academia Historica.

[87] "臺灣省煤業調節委員會工作報告 [Provincial Coal Adjustment Committee Working Report]" *臺灣省政府委員會議 [Taiwan Provincial Government Committee Meeting]*, Taiwan Historica Collection, no. 00501102407, Taiwan Historica.

(presumed to be around 120,000 to 170,000 tons). The KMT government implemented this reorganization to decontrol the coal market and thereby show the U.S. government its will to "return" to a free economy. The gesture was deemed essential to maintain support from the U.S. government.

The new marketing regulations enabled the coal operators to either sell their production at the PCAC's listed prices or the free market at any price. The government agency thus failed to achieve coal control when the market price fluctuated (higher than the PCAC proposed). The issues of supply shortage and delayed deliveries were amplified when the Nanpu power plant commenced in 1955. Aside from the TPC, TRA, Cement, Sugar, Paper & Pulp, Fertilizers, and Aluminum industries in Kaohsiung were the major consumers then. With the rising industrial demand from the south, a Joint Committee of Coal and Coke Supply and Distribution (JCSD) was established in the same year with seven members from the Taiwan Coal Mining Association and two from the PCAC to fulfill coal delivery better.

One of the solutions proposed by the TPC was to sign long-term contracts through PCAC, but the coal mine operators were somewhat reluctant to reach an agreement due to TPC's varied demand in dry and wet seasons. Additionally, considering the required long-distance shipment through railways, the TPC engineers valued the quality-control matter as critical as on-time delivery. The surface coals, for example, have higher moisture content, lower amounts of carbon contained, and lower heating value. The quality ranking of coal varies significantly, and the received quality of coal was even harder to control under the mandatory purchase channel via PCAC. This was a major problem as the Nanpu power plant would need coals with higher heating values to break even due to the transport cost.

A TPC engineer in charge of coal procurement wrote three articles to address this problem. For example, the poor-quality steam coals unfavorable to the market were sometimes delivered to the TPC instead.[88] Therefore, the TPC insisted on pricing on weight measurement rather than volume measurement, which made the deal much more challenging. Although the coal operators finally consented to sign the long-term contract through PCAC in 1958, the contracts still could not guarantee on-time delivery due to the PCAC's limited authority over the coal mines compared to its power over the national enterprises. For example, the TPC was prohibited from procuring coal in the free market even if the Ministry of Economic Affairs (MOEA) approved such a proposal in 1968. The Taiwan Provincial Government vehemently opposed and asked the Cabinet (Administrative Yuan) to revoke the decision.[89] It became clear that the "coal famine," which occurred multiple times, was a result of *management* failure. In other word, the domestic coal supply did not appear to be more

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[88] Gao-ming Wang, "採用台煤之經驗," [The experience of using Taiwan's coal.] *Monthly Journal of Taipower's Engineering*, no. 104 (1957): 14-19.

[89] "行政院會議議事錄 臺第二九五冊 1074 至 1075 [Proceedings of the Executive Yuan meeting, volume 295, 1074-1075]" *行政院 [Executive Yuan]*, Academia Historica Collection, no. 01400020500322001, Academia Historica.

stable or easier to control than water seasonality or imported fuel throughout the 1950s. As the unrectified coal procurement problem remained in place, the concurrent TRA's and Kaohsiung Harbor Bureau (KHB)'s extension projects in Kaohsiung, which were designed to help their transport system accommodate the increasing freight volume on the railways and at the port, offered TPC a solution to their coal problem – shifting to oil.

2.4.2 The shared infrasystems within the industrial zone

Kaohsiung Harbor, the once-small fishing port, gradually gained its crucial position in Taiwan's transport system in the Japanese ruling period.[90] It became Taiwan's major industrial city with the support of interlinked infrastructures. Along with the North-South railway reaching straight to the port and the infrastructural investments for enhancing the port facilities, roads, water, and sewer system, the city expanded rapidly with the emergence of Taiwan's first industrial cluster, the Shijia zone.[91] The industrial cluster rapidly grew into a capital-, labor-, and energy-intensive area following the end of the Second World War. Along with the gradual completion of the dredging works at its main fairway, the clustered heavy and machine manufacturing factories soon restored their productivity and demanded scaling up the integration of infrasystems for electricity, industrial water, and transport systems accordingly.

Commissioned in 1955, the first steam turbine in the Nanpu power plant could be seen as a fundamental step for such a co-evolution. The plant is situated at Basin No.5 of Kaohsiung harbor in the Shijia zone where the established factories could benefit from sitting at the heart of the infrasystems of the power grid, railway, port, and inland canals. The location also provided TPC's thermal power plant with cooling waters for the boilers, access to required coal through railways, and a channel to discharge the fly ashes afterward. The interlinked infrasystems generated synergy to fuel the dramatic industrial growth at the port.

Looking closely at the area, the TRA built multiple industrial sidings along the port railway route, enabling industrial products, raw materials, and coal to be directly transported from/to the warehouse and factories. The port railway functioned as the junction of ocean freight and inland railway transport.[92] During the 1950s, the first port railway route departure was established starting from the Kaohsiung Port, surrounded the Cheng-Chen District and nearby Linya District, and joined the North-South railway route with its destination stop, Kaohsiung Station. The circular line interlinked the factories through various industrial sidings, including the Nanpu power plant, Taiwan Aluminum Corporation, Steel Manufacturing, Taiwan Fertilizer

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[90] Liu Pi-chu, "The Influence of the railway and harbor development on the Kaohsiung city planning under the Japanese colonial rule," *Bulletin of Academia Historica*, no. 47 (2016): 1-46.

[91] Wang Yu-fong and Chen Huei-huan, "日治時期戲獅甲工業區的建立 [Establishment of the Shijia Industrial Zone in the Japanese Colonial Period]," *Kaohsiung Historiography* 5, no. 2 (2015): 104-30.

[92] Po-hsiang Chiu, "The transformation of Kaohsiung port railway route and space" (Master thesis, National Cheng Kung University, 2015).

Corporation (TFC), Combined Logistics Command's 205 munition factory, Kaohsiung Ammonium Sulfate Corporation (KASC), and Taiwan Machine Manufacturing Corporation's factories (TMMC). Meanwhile, they were also major electricity consumers who shared the 66 KV transmission lines in the Shijia zone as well. In return, these factories with special contract sales followed the TPC's cartel policies to adjust their usage and operation time. Especially for those intensive users, such as the chemical (fertilizer and alkali) and metal manufacturing industries (aluminum and steel), were the most affected throughout the 1950s.[93]

The Shijua area's development epitomizes Taiwan’s emerging carbon-intensive infrasystems. The coal-based Shijia industrial cluster reflected the Nationalist government's early industrial development goals to increase food, textiles, and daily necessities to accommodate the sudden population growth due to its retreat from the mainland. In return, those priorities made raw materials like alkalis, acids, and coal-based chemicals for producing chemical fertilizer remain essential and interdependent in the postwar Shijia industrial cluster and well into the 1960s. The coal-based industries became fixated on the industrial cluster with the integrated transport infrasystems and escalated their production in parallel with the infrasystems' extension.

As their productivity rose, the mounting pressure on the high handling cost of domestic coal at Kaohsiung brought the IDC into the picture. At the beginning of 1955, K. T. Li wrote to the JGW's Project Manager, V. S. de Beausset, regarding possible solutions. The JGW proposed to unload coal on the dock instead of the coal freight vehicles.[94] They believed that the island's economic future lay in exports, and thus, enlarging the port's capacity and handling ability was a necessary step. The coal problem could also be fixed through maritime logistics. At the time, however, the IDC was an industrial policy planning agency without much political power to push forward the overarching project. Bearing their suggestion in mind, Li later became the central figure in the subsequent Kaohsiung Harbor Extension Project (1958-1970) and the setup of the world's first Export Processing Zone (EPZ) at the port by the time he transferred to the CUSA from 1958 to 1963.

The coal transport problem was taken up again in 1960 when the major coal consumer, TPC, was looking forward to completing the third power-generating unit of the Nanpu power plant by 1963. The two units of 40 MW generators consumed around 300,000 tons of coal per year. After completing the third unit with its larger installed capacity of 125 MW, the yearly consumption was expected to double to 600,000-700,000 tons. In addition to TRA's insufficient coal freight vehicles, the disastrous flood of August 7, 1959, which damaged the

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[93] Yun-suan Sun, "臺灣 1955 年供電及業務概況," [A brief review of Taiwan's electricity supply and sales in 1955] *Monthly Journal of Taipower's Engineering*, no. 91 (1956): 1.

[94] "煤礦開採：煤礦運輸 [Coal extraction: Coal transportation]" *行政院經濟建設委員會 [Council for Economic Planning and Development]*, Academia Historica Collection, no. 0400104090019, Academia Historica.

North-South railway, also exposed the vulnerability of long-distance coal transport.[95] This time, the Transportation Project Coordination Group (subordinated to the Ministry of Transportation and Communication) held several meetings with the TPC, CUSA, Keelung Harbor Bureau, Kaohsiung Harbor Bureau, PCAC, and other relevant government agencies to conduct a thorough study on the feasibility of shipping coal from the Keelung port. They drafted the construction plan for a coal terminal at the fifth pier of Kaohsiung port. The KHB would build a coal wharf with coal unloading and conveying equipment in front of the Nanpu power plant to increase the flexibility of coal transport. By 1962, however, the TPC dropped this plan, claiming that they decided to fire heavy oil in the Nanpu power plants as they had another large-scale coal-fired thermal power plant in construction at Shenao, which location could make better use of domestic coal in Keelung.[96]

In fact, the grading works for the Shenao plant had already been set in motion in 1957 when the installation of Nanpu's second steam turbine was yet finished.[97] Furthermore, the JGW report on TPC's performance already proposed to initiate the second thermal unit rated at 125 MW in the Shenao plant.[98] Therefore, it is reasonable to infer that in 1962, what decisively forced the TPC to give up building a coal terminal was the revised Kaohsiung Harbor's extension plan instead. In the original diagram, the Shijia zone would face the main fairway and have a deep-water wharf right before the Nanpu power plant, allowing at least a fifteen thousand tons bulk carrier to berth. The CUSA had stressed this point since the project had launched to help the TPC get enough coal by waterways. Nevertheless, in the end the waterway in front of the Nanpu power plant became the branch fairway, only enabling ships under five thousand tons to enter. The resulting restricted capacity failed to decrease the shipping cost, and the two generators of the Nanpu power plant began to fire heavy oil instead of coal in 1966.

From the TPC's perspective, the interruptions of domestic coal supply remained unresolvable under the PCAC's management failure and the saturated railway system throughout the 1950s. The following expansion of fuel supply infrasystems and peer industries led it to an alternative option: fuel oil.[99] Being aware of the temporary nature of the U.S. aid, the state launched several projects to increase its accumulated reserves of foreign exchange,

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[95] TRA "八七水災重建工程 [August 7 Flood Reconstruction Project]", National Archives Administration Collection, no. A315180000M0048296001, National Archives Administration, National Development Council.

[96] "電力公司南部用煤海運計畫案 [TPC's coal shipping plan for the southern area]" *行政院經濟建設委員會 [Council for Economic Planning and Development]*, Academia Historica Collection, no. 0400106000018, Academia Historica.

[97] Shi-zhong Li, "臺灣電力系統中之火力發電," [Thermal power generation of Taiwan's power system.] *Quarterly Journal of Bank of Taiwan* 19, no. 3 (1968): 130-58.

[98] TPC "Power system development: TPC part-I, power requirement and generating capability" *Valery S. de Beausset Collection*, no. ntul_db03_03_003, National Taiwan University Library.

[99] Shih-chuan Chou, "火力發電廠之廠址選擇," [The site selection of thermal power plants.] *Monthly Journal of Taipower's Engineering*, no. 125 (1959): 11-23.

including the 12-year Kaohsiung Harbor Extension Project, the setup of Free Trade Zone, which later was designed as the EPZ, and the emergence of the petrochemical industry in Kaohsiung during the 1960s. The proximity to chemical feedstocks extended the linkage of carbon-intensive infrasystems from the port to the southern and northern parts of Kaohsiung and the harbor extension project well into the 1970s. In return, it reshaped Kaohsiung harbor's economic and energy landscape in terms of the composition of TPC's major power users. For example, by 1967, the chemical industry had replaced the fertilizer industry as the most significant power user on the grid. While the present section explained the reasons that triggered the TPC to change their mind about domestic coal, the following section will explore how the fuel supply infrastructure development enabled the TPC to gradually phase out domestic coal by 1968.

2.5 Shifting to oil in the 1960s

Nanpu power plant's location adjacent to the oil terminals in Lingyaliao district suggests convenient fuel access. Since the needed pressurized steam could be generated by firing either dust coal or heavy oil, all the TPC engineers needed to do was attach additional fuel pipes to the boilers without bothering to install other supporting equipment such as a conveyor belt, coal pulverizer, or fly ash handling facility that would have resulted in higher construction cost. The interchangeable fuels gave the TPC flexibility to have their operational costs under optimal control. In other words, shifting to fuel oil did not mean abandoning coal once and for all but, on the contrary, a continuation of TPC’s coal dependency. More precisely, TPC engineers' prior experience with domestic coal had, in fact, led to their further diversification of fuel options with corresponding types of thermal power units. This trend emerged in the 1960s; for example, aside from heavy oil, gas turbines were connected to TPC's grid as well, while the existing three steam power units in the Nanpu power plant adopted light diesel oil in 1967. This added layer of petroleum in its electricity mix was made possible in the context of the island’s increasing oil refining capacity and emerging petrochemical industry from the late 1960s. The remainder of this chapter explores the interacting factors that favored such a shift from three aspects – TPC's fuel procurement channel, fuel supply infrastructure, and the reshuffling composition of the major power consumers.

First, TPC's fuel oil source was under the state-owned Chinese Petroleum Corporation's (CPC) control. Becoming one of TPC's fuel suppliers, CPC had eased TPC's pressure in dealing with coal mines through levels of governmental agencies. Unlike PCAC, which faced constraints in its role as an intermediator, CPC had a better prospect and resources in terms of advancing facilities and personnel training in chemical engineering, production facilities, and export opportunities with an array of petrochemical products to achieve self-sufficiency and assure a stable growth of fuel sources. Moreover, CPC and TPC shared the same visions of the Nationalist government to support national industrial growth.

The establishment of the Union Industrial Research Institute (UIRI) in 1954 was an example showing CPC's and TPC's efforts in meeting such a national goal through scientific collaboration. Called upon by IDC, the UIRI was established at the former CPC's Hsinchu Research Institute with funding from CPC, TPC, Taiwan Sugar Corporation, Taiwan Fertilizer Corporation, Taiwan Alkali Company, Taiwan Aluminum Company, Taiwan Cement Corporation, and Taiwan Pulp and Paper Corporation. It represented Taiwan's first centralized applied research center that aimed to stimulate research-industrial cooperation among industrialists, government officials, the chief of staff of the technical sector in the military force, and university professors.[100] In other words, CPC's importance in regard to TPC's system was not only for its role as TPC's fuel supplier but also as the coordinator in supporting Taiwan's industrial development through the interlinked fuel and power supply infrastructure in the industrial zones. While the coal supply infrasystems were concentrated in northern Taiwan, CPC's oil supply infrasystems were built in the south during the short-lived "Free China" polity on the mainland from 1946 to 1949.

In order to understand under what circumstances TPC's fuel shift to oil became possible, it is necessary first to detail the historical context of Taiwan's oil trade. China entered the global oil trade in the late 19th century when the late Qing dynasty was in turmoil due in part to forced trade treaties. The oil giants, the Standard-Vacuum Oil Company, the Shell Company of China, Ltd., and the Texas Company (China) Ltd, introduced kerosene (for lighting), Diesel, and fuel oil to China. Many oil terminals and storage facilities were built in coastal cities, but no refineries. Only later, the Japanese established refineries at Manchuria (Northeast Region) and Formosa (Taiwan) that could perform fractional distillation of crude oils.

Founded in Shanghai in 1946, CPC immediately took over the storage tanks relinquished by the Japanese and the extraction rights for oil fields across the mainland and Taiwan. Two companies, including the Imperial Oil Co. and Nippon Petroleum Corporation, and one small-scale refinery operated by the Japanese Navy – Sixth Naval Fuel Plant (renamed the Kaohsiung Refinery) at Tsoying – were subsequently integrated into the CPC's assets. The accumulated facilities added up to 30 percent of the total oil storage in China, and most importantly, taking advantage of its biggest shareholder – the NRC's capital and a direct channel with the cabinet – enabled the CPC to integrate the oil shipping business vertically and thus to remain competitive with the international oil corporations. This relationship, in return, helped the government to obtain imported oils under the established regulations regarding the allocation, price, and import quota of petroleum products. The extra quota was only granted access to

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[100] Y. S. Sun, TPC's Vice President and Chief Engineer at the time, was one of the initial members of the advisory committee of Union Industrial Research Institute. When he became the Minister of Economic Affairs, he merged the research institute with the Mining Research and Service Organization and Metal Industrial Research Institute and turned them into the Industrial Technology Research Institute (ITRI) in 1973. ITRI represents the primary R&D center that boosted the transformation of Taiwan's industrial structure toward high-tech industries during the 1970s and yields substantial influences on Taiwan's renewable energy's development. The latter will be discussed in detail in the fourth chapter.

keep the KMT regime running – military, national highway administration, national shipping, railways, and airline usages – aligning with national strategic considerations.

Through joint ventures, CPC, NRC, and China Merchants Steam Navigation Co. co-founded China's first oil tanker company in 1947, carrying crudes from the Persian Gulf by ocean-going tankers and transshipping bulk stocks between the domestic ports and along the Yangtze River by coastal tankers.[101] It is clear that Taiwan's early oil economy was closely attached to the market on the mainland. According to the oil shipping record, the petroleum products in contracts with foreign companies mainly were kerosene and gasoline, while the CPC's was heavy oil from the Kaohsiung Refinery and imported Kuwait, Iran, and Arabian crudes.[102] Compared to the transport system of Taiwan's domestic coal, Kaohsiung harbor represents a crucial node of CPC's trading network. It replaced the military port, Tsoying Naval Base, as the main oil terminal thanks to the severe congestion with shipwrecks at Tsoying port and the fact that the CPC had no authority over the military's territory.[103] Subsequently, the CPC turned to the two KHB-operated wharves at Kaohsiung harbor and laid the relatively longer pipelines to pump crude oils to the Refinery in 1947.[104] This newly installed pipeline system consisted of two 6-inches crude oil pipes and two 4-inches light oil pipes that together could handle 15,000 bbl/pd of crude or heavy oil and 5,000 bbl/pd of light products.[105] Simultaneously, the rehabilitation plan for the Refinery was also underway in which two topping units and one thermal cracking unit were revamped and put on stream to produce gasoline, kerosene, diesel fuel, fuel oil, and asphalt from sweet crude (with higher sulfur content comparing to sour crude). By 1950, the Refinery's production capacity was thus multiplied from 6,000 to 12,000 bbl/d. Aside from the pipelines, CPC's manufactured white products were distributed to various end-users by tank trucks along rails while the black stocks were sent by waterway to the Keelung port.[106]

Compared to domestic coal, fuel oil's delivery depended upon the stable output from oil-exporting countries, harbor capacity, and the security of long-distance pipelines. Multiple interruptions had occurred in the initial stage of the Refinery's development either because the depth of the Kaohsiung Harbor's main entrance was less than 33 ft, which could not admit

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[101] "各石油事業組織通則規程案 [General rules and regulations for various petroleum industry organizations]" *資源委員會 [NRC]*, Academia Historica Collection, no. 0030107000055, Academia Historica.

[102] "中國油輪公司民國三十六年度營業報告書 [China Oil Tanker Corporation's business report in 1947]" *資源委員會 [NRC]*, Academia Historica Collection, no. 0030103010888, Academia Historica.

[103] Ming Huang and Bao-qian Lu, *金開英先生訪問紀錄* [An Interview of Jin Kai Ying] (Institute of Modern History, Academia Sinica, 1991), 201.

[104] TRA "油管鋪設修復及代辦石油支線工程 [Oil pipeline laying and repair and oil pipeline engineering tasks]" *交通部臺灣鐵路管理局 [TRA]*, National Archives Administration, National Development Council, no. A315180000M0035245017, National Archives Administration, National Development Council.

[105] CPC "中國石油公司報告 [CPC's report]" *資源委員會 [NRC]*, Academia Historica Collection, no. 0030202000046, Academia Historica.

[106] CPC "中國石油公司報告 [CPC's report]", no.,

oil tankers carrying over 10,000 tons of crudes or oil spills from the damaged pipelines. CPC's investments in the China Oil Tanker Company show the attempts to reduce the shipping problems; it also urged the government to draft stricter punishments for stealing oils while expecting the harbor's further extensions. In so doing, it further bounded the TPC and CPC system in the south. Its development trajectory exemplifies Taiwan's crucial transitions of economic policy, industrial structure, and energy mix well into the 1970s.

As Marten Boon observed for the Rhine region, the incumbent chemical clusters shifted from coal to hydrocarbon feedstocks, boosting a growing oil demand from the midstream manufacturers. The energy transition significantly reshaped the economic geography from inland to port clusters in the Rhine region during the 1950s and 1960s. Boon further notes that "underlying the energy transition was a growing demand for a wider array of oil products — from lubricants to gasoline, Diesel, jet fuel, feedstock, and fuel oil — that was caused by the growth of motorized transport and the concomitant expansion of tarmacked roads, innovations in petrochemicals, and increasing use of oil for energy and heating. The expanding market attracted refineries to Europe, and these required a new infrastructure of transshipment facilities in seaports and pipelines to inland refinery locations."[107] Also resembling the path that resulted in the rapid extension of Rotterdam port, Taiwan's Kaohsiung port city underwent a significant change with the energy transition from domestic coal to oil characterized by a deep involvement by the state, municipal government and national enterprises such as TPC and CPC.

As CPC's oil facilities were gradually installed along with the port's extension project, the evolving oil infrastructure resulted in the early formation of Taiwan's first petrochemical complex. Furthermore, the petrochemical landscape also yielded impacts on the TPC system's energy decisions with regard to the addition of oil as an energy source, their designs for steam turbine units, and their consumer structure. Therefore, tracing Kaohsiung port's subsequent extension projects will offer clues to explain how shifting to fuel oil and TPC's dependency on imported energy became possible during the 1960s.

The Kaohsiung harbor's 12-year extension plan from 1958 to 1970 covered four major tasks: fairway dredging, land reclamation, shallow water quay (revetment for absorbing the impacts of incoming water), and deep-water wharf building. Using the dredged soil from the fairway channel to fill up the shallow water areas and fishponds along shore provided the space and deeper waterways to gradually fulfill the nation's goal to decrease its dependency on U.S. aid. According to KHB's plan in 1967, the planned land use of the reclaimed areas included commercial port areas, industrial zones, fishing ports, shipbuilding yards, and oil terminal districts. CPC's oil terminals and storage facilities used to be situated in the old harbor area, as well as TPC's Nanpu power plant. Considering the security and safety issues for oil

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[107] Boon, *Multinational Business and Transnational Regions: A Transnational Business History of Energy Transition in the Rhine Region, 1945-1973*.

facilities in the city center, the KHB planned to move the oil terminals to Tar-Ling-Pu. The required larger berth capacity of 75,000 tons deadweight (the maximum weight for a loaded vessel) was provided by the subsequent "Second Harbor Entrance Construction Project" planned for completion in 1975. In so doing, when the TPC planned to apply heavy oil in the Nanpu plant, another power plant, Talin thermal power plant, was already in progress. The decision was made based on the ideal depth of the fairway to build the coal terminal and the adjacent location with the CPC's Talin oil terminal, which was designed to receive crudes and transship petroleum products to northern Taiwan. The Talin power plant was thus equipped with TPC's first two thermal units designed to burn heavy oil only.[108]

As Chu Shu-Lin pointed out in 1966, what concerned TPC the most regarding its coordination with CPC was the technical problem of keeping the balanced output of white and black oil products within the refining process.[109] Indeed, during the 1950s, most of CPC's efforts were devoted to the Kaohsiung Refinery's modernization projects to increase gasoline yields and quality with a higher-octane number to meet the military's expectations and export. Its Fuel Research Laboratory of the Union Industrial Research Institute also made improving the quality of cracked gasoline from Kaohsiung Refinery its primary research project. Therefore, although its performance had reached 60,000 bbl/d by the late 1960s, the large amount of TPC's petroleum demand for heavy oils had to be met partly by importation and partly by CPC's refining production. The completion of the Talin power plant marked TPC's beginning of dependency on energy imports.

Another impetus behind TPC's plan to increase the number and unit capacity of steam and gas turbines in Kaohsiung came from the changing industrial structure, i.e., the composition of power-intensive users at the newly developed harbor. Expecting the future prosperity of the reclaimed development zones along the extending Kaohsiung harbor, K. T. Li created the South Taiwan Industrial District Development Committee in 1960. As mentioned before, his former position in the IDC made him fully aware of the domestic coal delivery problem. The Committee had allowed him to use land and import taxes as incentives to promote private investment in Kaohsiung's midstream and downstream petrochemical industries. In other words, it was to replace industrial feedstocks from coal- with petrochemical-based raw materials. Among them, synthetic fibers and plastic were the industries targeted for export.

As mentioned earlier, the Shijia industrial cluster in the old harbor area exemplifies the agglomeration of the inorganic acid- and fertilizer-based light industries. As a U.S. aid project, a new chloralkaline polyvinyl chloride (PVC) resin unit was installed by the privately-owned Formosa Plastic Corporation in Shijia District in 1957 to acquire chlorine and hydrogen in

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[108] Shu-lin Chu, *Power Development in a Developing Country: Experience with Taipower (1946-1985)* (Taipei, Taiwan: Taipower Company, 1987), 350.

[109] Shu-lin Chu, "臺灣發電經濟能源芻論," [A discussion on Taiwan's energy economy of power generation.] *Monthly Journal of Taipower's Engineering*, no. 216 (1966): 1-10.

gaseous form through two pipelines directly from the Taiwan Alkali Corp., located across the canal.[110] Before using ethylene as feedstock, the calcium carbide process resulted in high electricity consumption. In return, the expansion of the Kaohsiung PVC plant was confined to the chlorine supply from Alkali Corp. Therefore, replacing the manufacturing process with petrochemicals meant substantial changes in its production capacity and linkage within the chemical industry at the port.

As suggested in the observation report of 1962 regarding the planning of the industrial zones at Kaohsiung Harbor by Andrew Brendan O'Regan, the Director of Ireland's Shannon Free Airport, "a distinction must be drawn here between, on the one hand, an agglomeration of industries which have been developed around a port or airport, railway junction or reclamation scheme and, on the other hand, a planned industrial complex such as an oil refinery-petrochemical plant-synthetic fiber industry."[111] His recommendation of building the petrochemical complex to attract private investments was in line with the government's proposal to gather the PVC and Man-made fiber manufacturing factories around the Kaohsiung Refinery.[112] This vision was realized in 1968. C. K. Yen, the incumbent Vice-president and also the Minister of Administrative Yuan (the cabinet), held the co-opening ceremony of CPC's first naphtha cracking plant in the Kaohsiung Refinery and USI Corporation's first LDPE (low-density polyethylene) Kaohsiung plant. Nearby the Kaohsiung Refinery, the Jenwu Petrochemical Industrial Park, was established in 1972; the following year, CPC built two oil distillation plants at the Talin oil terminal to directly support the TPC's fuel demands with the imported crudes without detours to the Kaohsiung Refinery. The growing refining capacity of the Talin oil terminal later became the center of Taiwan's largest-scale petrochemical complex, Linyuan Industrial Park, located at the end of the extended Kaohsiung Harbor. From 1967 onward the chemical industry became TPC's most significant industrial power user, thereby moving the nodes of the carbon-intensive networks from the old harbor area to northern and southern Kaohsiung, respectively.

Looking back to the 1960s, TPC's search for fuel flexibility met with the CPC's growing interest in extending its business to the mid-stream petrochemical industry. From 1963 to 1969, the natural gas deposit was successfully extracted in Miaoli County, the Northern West of the island. CPC grasped the sub-investment opportunity and co-founded Mobil China Allied Chemical Co. through a joint venture with the U.S. Mobil Oil Co. and Allied Chemical Co. to

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[110] "化學工業總卷 [Chemical industry general volume]" *行政院經濟建設委員會 [Council for Economic Planning and Development]*, Academia Historica Collection, no. 0400104100010, Academia Historica.

[111] Andrew B. O'Regan "The Development of Industrial Districts in Taiwan" *Council for Economic Planning and Development, Executive Yuan*, Academia Historica Collection, no. 040-010600-0007, Academia Historica.

[112] MOEA "The 89th meeting of the Minister of Economic Affairs " *Council for Economic Planning and Development, Executive Yuan*, Academia Historica Collection, no. 040-010500-0006, Academia Historica.

utilize the extracted natural gas to produce urea fertilizer. As for TPC, it built the Tunghsiao Power Plant with gas turbines. The possibility of harnessing domestic oil and natural gas had brought hope to the coupled TPC and CPC system and was reflected in Taiwan's first energy policy of 1968.

The Energy Development Planning Group, under the supervision of the Council for International Economic Cooperation and Development (CIECD, the superseding agency of CUSA), drafted "Taiwan District Energy Development Principle."[113] Approved by the Executive Yuan as part of the fifth 4-year Industrial Development Plan,[114] the Plan declared that oil would be Taiwan's primary energy carrier for the next decade. Continued efforts should be made to explore domestic oil fields and natural gas wells. On the other hand, considering the TPC's financial burden of fuel cost, the Plan lifted the imposed import and excise tax on fuel oil. In addition to the major contribution from thermal power, nuclear energy was expected to power baseload plants as well, and thus, nuclear fuel should replace oil as the essential power-generating source in the long run. Figure 9 shows the optimistic energy forecast addressed in the later implemented “Taiwan District Energy Policy” of 1973.

With hindsight, TPC's subsequent development of nuclear power did not serve as a substitute but contributed to TPC's dependency on fossil fuels well into the 1980s. After introducing oil to Taiwan's electricity mix, its share went from 27.7 percent of the total electricity generation in 1966 to its peak of 80 percent in 1977. The next chapter will discuss such scaling-up of the carbon-intensive infrasystems with the TPC's energy decisions amid the economic and political turbulence in the long 1970s.

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[113] The convenor of the Energy Development Planning Group was the then advisor of the CIECD and Minister of Transportation, Sun Yun-suan. Sun’s background as TPC’s former chief engineer made him the central figure in the inauguration of Taiwan’s first comprehensive energy policy in 1968. Regarding the meetings, see "李國鼎 行程三 [Kuo-Ting Li, personal schedule three]" *行政院國際經濟合作發展委員會時期大事記 [Major events during the period of the CIECD]*, Archives, Institute of Modern History, Academia Sinica, no. 051010111022003, Institute of Modern History, Academia Sinica; "李國鼎 行程一 [Kuo-Ting Li, personal schedule one]" *行政院國際經濟合作發展委員會時期大事記 [Major events during the period of the CIECD]*, Archives, Institute of Modern History, Academia Sinica, no. 051010119002001, Institute of Modern History, Academia Sinica.

[114] Ming-dong Lin, "台灣之能量資源," [Taiwan's energy resources.] *Quarterly Journal of Bank of Taiwan* 20, no. 2 (1969): 1-30.

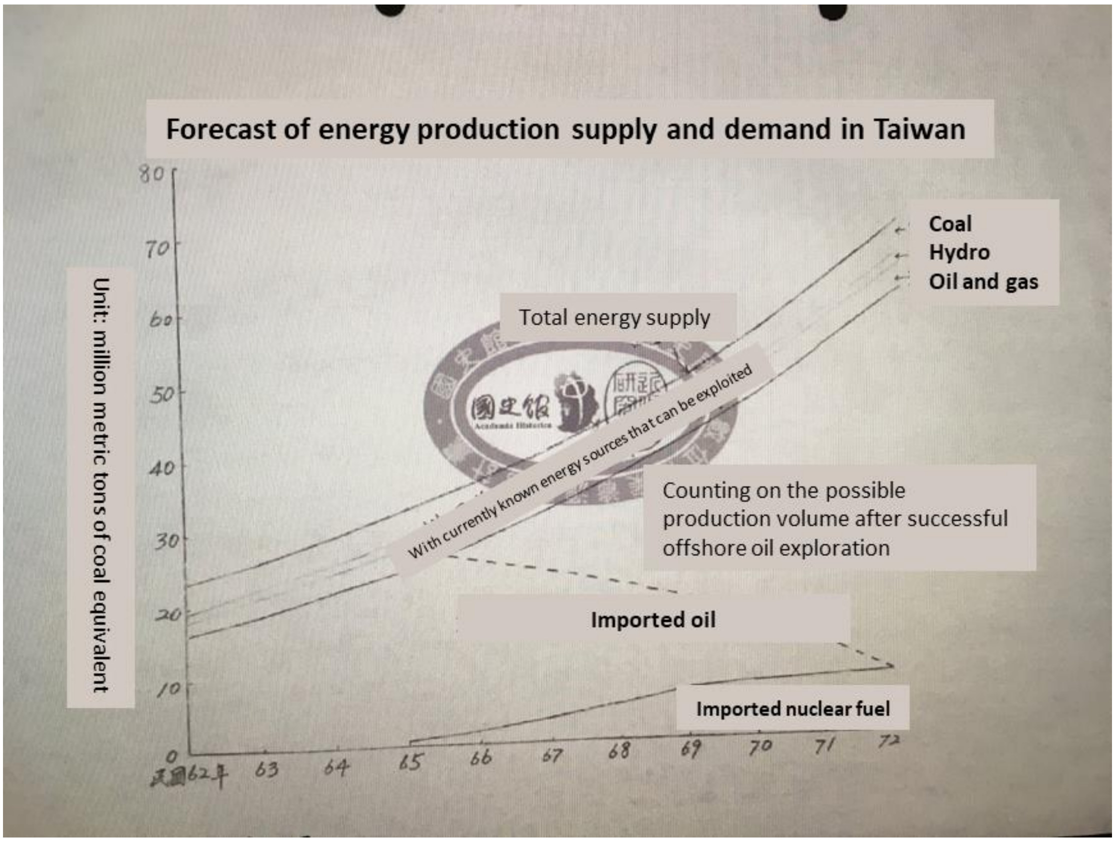

Figure 9 A diagram of the predicted Taiwan's energy production in 1968.

The x-axis indicates the year of the ROC era, which in CE is from 1973 to 1983. The unit of the Y-axis suggests million metric tons of coal equivalent. The upper escalating line suggests the currently known exploitable amount of coal, hydropower, and oil; the dotted line refers to the possible production amount from offshore oil exploration. The bottom indicates a growing supply of imported nuclear power (fuel).

Source: Excerpted from "能源政策 [Energy Policy]," in 外交部 [Ministry of Foreign Affairs] (020-130800-0046, Institute of Modern History, Academia Sinica: Archives, Institute of Modern History, Academia Sinica, 1973).

2.6 Concluding remarks

This chapter revisited the TPC system's post-war development from 1945 to 1968 to understand how a hydro-based power system gradually increased its dependency on fossil fuels and later shifted from domestic coal to imported fuel oil. Examining the TPC system's reconstruction based on its colonial past and the close relationship between TPC engineers and high-profile statesmen, the first section highlighted how the landscape of power supply and consumption was further polarized under the Nationalist government's planned economy, and how the subsequent imbalanced regional load greatly influenced TPC's energy choice. To cover the rapid growth of industrial power in load centers, TPC turned to thermal power units with relatively low construction costs in terms of time and resources. Especially with the help of US aid, the number and scale of steam turbines started to soar in the 1950s. Although there were different opinions among TPC engineers suggesting better utilization of hydropower and doubts about the thermal power plant's higher fuel cost, the second section explained how the TPC’s decision to apply domestic coal was linked to the completion of the coal-fired Nanpu power plant nearby the Kaohsiung port in 1955.

While Taiwan's domestic coal fields were distributed in the northern region, TPC's decision to burn domestic coal in the Nanpu power plant required integration with the railways and ports. The third section delved into the origin of TPC's fossil-fuel transporting network that co-evolved with the nearby industrial zone, Shijia, in southern Taiwan. However, the delivery and quality problems of the long-distance domestic coal had stalled TPC's further expansion plan with more steam turbines. Another shift to imported oil became an ideal option for TPC. Concurrently, the revamped petroleum refining industry shifted feedstocks from coal- to petroleum-based raw materials. The subsequent evolving petrochemical industry provided access for TPC to replace domestic coal with heavy fuel oil. As TPC and CPC systems got more closely tied with their fuel transport system, their needs for deeper fairways at Kaohsiung port also shaped the port city's landscape and signaling the beginning of the fixated carbon-intensive infrasystems and, thus, Taiwan's dependency on imported fossil fuels.

In retrospect, Taiwan experienced multiple energy transitions as diverse energy-converting technologies were added to the TPC system. Through the lens of infrasystems, the shifting energy mix suggests that compared to the worries over coal exhaustion or the lack of ideal sites to build large-scale hydropower plants, TPC struggled more with the coal managing problems, imbalanced regional load, and the changing industrial users in the early postwar years. A systemic and integrated perspective underlining the configuration of the power system, railways, ports, pipelines, and the types of end users is required to map out such path dependency toward hydrocarbon fuels. More importantly, it can help to explain Taiwan’s subsequent energy choices as their hopes for oil and nuclear power converged with political realities and challenges.

Chapter 3: Rethinking the Energy Crises of the 1970s and their Aftermath

3.1 Introduction

TPC's dependency on fossil fuels started to emerge in the mid-1950s. The previous chapter noted that shifting from domestic coal to imported oils was not only a matter of adding pipes to TPC's thermal power units but also required a substantial investment and co-evolution with the oil storage, transport, and industrial infrastructures. In accordance with the growing capacity of railways, ports, and CPC's refining and exploration business, TPC was able to allocate domestic coal, diesel oil, heavy fuel oil, and domestic natural gas to its system. By 1968, these sources fueled the thermal power units to meet the island's baseload power which amounted to 40.5 percent of total electricity generation. Fuel oil was attractive all over the world not only for its features of lower sulfur content, lack of ash, and higher heat value compared to steam coal, but also for its greater accessibility through waterways and pipelines. Moreover, its price remained stable and relatively low until the "oil shocks" in the 1970s provoked alarm among oil-dependent countries. According to Taiwan's 1968 energy development principle, foreign oil was expected to become a part of the solution for dealing with the problems of domestic coal.[115] Yet the subsequent energy crises, global economic recessions, and Taiwan's increasing losses of diplomatic allies significantly hampered Taiwan's thermal power-based system.

In the 1970s, Taiwan withdrew from the United Nations as a protest against the General Assembly resolution of 1971 that allowed the PRC to become the legal representative of "China." In dealing with the era’s economic and diplomatic disturbances, the KMT government launched major infrastructural projects to stabilize the political environment domestically and internationally. In turn, the nation’s infrastructural program enabled the continued expansion of the TPC system and fuel network. As this chapter will show, on the one hand, fuel trades and transportation networks to keep the oil flowing became the foundation of maintaining the KMT's legitimacy on the island. On the other hand, escalating pressure to act against environmental hazards caused by the externalities of the carbon-intensive infrasystems also set in motion an alliance between grassroots organizations and pro-democracy movements which significantly challenged the Chiang family's ruling legitimacy and TPC's planning authority in the late 1980s. In the critical decades from the 1970s to the 1990s, Taiwan's energy politics became deeply rooted in the entangled fuel systems, political struggles, and emerging ecological perceptions of an ideal human/non-human relationship.

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[115] "行政院會議議事錄 臺第二九五冊 1074 至 1075 [Proceedings of the Executive Yuan meeting, volume 295, 1074-1075]", no.,

By revisiting TPC's energy decisions in this period, the following discussion explains how the aftermath of the energy crises is much more complicated than what has been described in the existing literature as simply a diversification of energy sources based on the nation's growing awareness of the idea of energy security.[116] Instead, the annual statistics show that the electricity generated by oil-fired units actually peaked at 80 percent in 1977 (see Figure 10). It was not until 1982 that the downward slope became steep. This suggests that the TPC system could still keep firing oil after the first and second spikes in oil prices (in 1973 and 1979, respectively). How and what turned the tide afterward?

In answering this question, this chapter has three primary goals. First, to clarify the different political and economic interests carried by different fuels in the first and second energy crises. Second, to explain the role of nuclear power in helping to sustain the thermal power-based system. Third, to argue that the problems of Taiwan's current renewables transition can be traced back to its energy past of the late 1980s. Focusing on the TPC engineers' responses to the multiple crises, this chapter underlines the persistence and scaling-up of the carbon-intensive network from the 1970s onward.

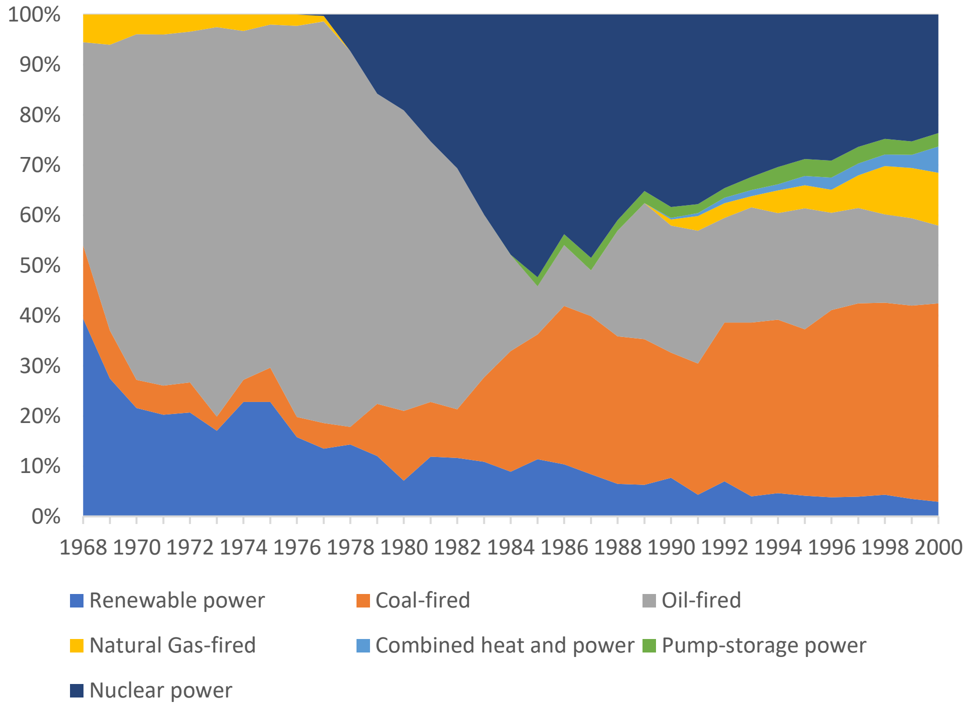

Figure 10 TPC's power generation by energy sources from 1968 to 2000.
Source: Data extracted from TPC's website and organized by author.

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[116] See for example, Wu et al., "我國能源政策發展模式及其未來方向探討 [Discussion on our country's energy policy development model and its future direction]."

3.2 The Political Economy of Coal, Fuel Oil, and Nuclear Material

Twelve days after the Yom Kippur War broke out in 1973, the then Prime Minister, Chiang Ching-kuo, made a statement about the current challenges in a cabinet-level meeting.

> In this fast-changing world, the Middle East War erupted again, which was entangled with international factors. In other words, if the geopolitical problems could not be tackled at their roots, the war might not be so easily ended as the Six-Day War [in 1967] the last time. All these situations will impose direct or indirect impacts on us… We need to take more time to consider these problems from a broader view.[117]

Although the cease-fire came into effect one week after the meeting, this passage clearly shows that the energy question was embedded in broader insecurity regarding Taiwan's position approaching the end of the Vietnam War and domestic political stability. The Prime Minister's concerns provided a glimpse of the political milieu at the time. Observing the neighboring countries, the four times higher oil price and cutback in supply in 1973 was one of the focal issues of the era's political transitions in East Asia. On top of that, the Paris Peace Accords in early 1973 and American setbacks in Vietnam hinted at the ensuing regional turbulence. Although the price of oil rose dramatically in late 1973 and early 1974, a significant increase in the oil price had been widely predicted ever since nationalization of oil assets in the Middle East began in the late 1960s. For countries as Taiwan in East Asia, the withdrawal of American troops from Vietnam did as much, or perhaps more, to upset the status quo of the political and economic situation.[118]

For instance, the mounting pressure on inflation, low-paid jobs, and unemployment rates caused by the economic crisis of oil shock resulted in large-scale protests against military dictatorships in Indonesia, Thailand, and the Philippines.[119] For example, afraid of possible chain reactions of economic failures resulting in domestic political instability, the then President of the Republic of Korea, General Park Chung Hee, established the Yushin Constitution that allows the holding of presidential elections but without limited terms of serving. In turn, the Yushin system was framed as “Korean-style democracy,” but in fact, Park’s continuing personal ruling power was institutionalized and normalized under such a

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[117] "行政院會議議事錄 臺第四〇九冊一三四五至一三四七 [Proceedings of the Executive Yuan meeting, Volume 409, 1345-1347]" *行政院 [Executive Yuan]*, Academia Historica Collection, no. 01400020500436002, Academia Historica.

[118] Giuliano Garavini, *The Rise and Fall of OPEC in the Twentieth Century* (Oxford University Press, 2019), 420; Brian C. Black, *Crude Reality: Petroleum in World History* (Rowman & Littlefield Publishers, 2012), 288.

[119] Even for petroleum abundant countries as Malaysia and Indonesia, the oil majors such as Exxon, Mobil, Shell, Caltex, and British Petroleum had directed their crudes to Japan and the United States, and left the domestic needs had to rely on the import of Persian Gulf crudes. See Robert F. Ichord, "Southeast Asia and the World Oil Crisis: 1973," *Southeast Asian Affairs* (1974): 27-56.

scheme.[120] At the same time, the KMT launched the "Taiwanization" strategy by enrolling Taiwanese elites into its party and cabinet-level agencies in the early 1970s to ease social tensions.[121] In short, the 1970s represents a critical period to observe how the energy decision to shift to fuel oil in the late 1960s and the geopolitical factors in East Asia yielded complicated impacts on Taiwan's development path. The decreasing economic growth rate and the loss of diplomatic ties had the potential to severely threaten KMT's ruling power.

The PRC's increasing influence somewhat limited Taiwan's international channels; growing diplomatic isolation exacerbated the government's concerns over Taiwan's oil dependency. Nevertheless, there were still channels that remained open. One was the informal relations built on transnational engineers' technical assistance, which proved to help achieve diplomatic goals. By looking closely into how TPC engineers' agency was mobilized to ensure stable crude imports to Taiwan, this section argues that it would be a gross over-simplification of Taiwan's strategy for dealing with the 1973 crisis if only the amended energy policies were taken into account. Such an oversimplified picture fails to explain why Taiwan's power system could continue firing fuel oil through the 1970s and 1980s. In addition to policy responses such as energy diversification and conservation that Taiwan had in common with other affected countries, TPC's diversification investments into mining, transporting, and storage business, and its transnational technical assistance projects suggest how the corporation helped to manage the insecurity of the state's geopolitical situation and uncertainty of imported coal, fuel oil, and nuclear technology in that period.

To further stress my point, first, TPC began its energy diversification strategy long before the 1973 energy crisis. As the last chapter revealed, the TPC system had grown into a carbon-intensive network with close ties with the CPC and the surrounding petrochemical industries in the late 1960s. The power system was attuned to large-capacity units with relatively low operational reserves. Especially after installing the 500 MW units in the Talin power plant, TPC adopted their design as the standard capacity of steam turbines to expand the baseload supply quickly. Shifting to imported oil was a decision to increase fuel flexibility for this thermal power-based system.

Second, expectations regarding continued dependence on fuel oil were reinforced in 1973 when CPC launched offshore oil exploration under the Taiwan Strait and the northern territorial seabed. Meanwhile, the government reiterated its ambition to develop the petrochemical industry under the Ten Major Construction Projects (1974-1979) framework,

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[120] Kang Ro Lee, "Bureaucratic-mobilizational regime: The Yushin system in South Korea, 1972-1979," *Asian Perspective* (1990): 195-230.

[121] Scholars addressed the political turmoil in South Korea, which applied a similar industrial development approach as Taiwan under an authoritarian regime after the Korean War. See Khairy A. Tourk, "Oil price shocks and the Asian newly industrialized countries' response: A case study of South Korea and Taiwan," *The Journal of Energy and Development* (1991): 255-66; Jei Guk Jeon, "The political economy of crisis management in the third world: A comparative study of South Korea and Taiwan (1970s)," *Pacific Affairs* (1994): 565-85.

which covered the already planned construction of railway extensions, harbors, international airports, heavy chemical industries, and nuclear power plants. The aforementioned Linyuan petrochemical industrial complex was one of the projects. At Kaohsiung Harbor's newly dredged second entrance, CPC built its third naphtha cracking plant inside the park next to TPC's Talin power plant. Given such sunk costs, it is unsurprising that TPC was not yet ready to give up on fuel oil after the first oil crisis; alternatives such as small-scale solar, wind power, low-headed hydropower, and ocean thermal energy conversion remained in research or experimental phases. In other words, TPC already anticipated a growing energy dependency on imported fuels in the early 1970s.

As this section will show, TPC’s main strategy for navigating the crises of the 1970s was risk distribution, about which the engineers had already learned their lesson when procuring domestic coal. From the TPC’s perspective, the 1973 oil crisis was perhaps not so much of a shock since they had already deployed national and international action to vertically integrate the power system into mining (including coal and uranium), and fuel storage, and transport facilities.

3.2.1 The 1973 oil crisis: Dealing with foreign fuels and diplomatic relations

In the late 1960s, the problematic supply of domestic coal motivated TPC's shift to fuel oil. At the time, the Ministry of Economic Affairs encouraged this change by offering TPC a lower oil price, 40 percent off the average. Subsequently, TPC's coal demand dropped from 1.31 million tons in 1965 to 110 thousand tons in 1973. However, the oil embargo of that year challenged the logic of shifting from coal to oil. Nevertheless, TPC's engineers played a central role in keeping fuel oil's promise to help decrease TPC's reliance on domestic coal.

Sun Yun-suan, the Minister of Economic Affairs between 1969 and 1978, was an influential figure for his background as TPC's former chief engineer and manager. He departed to visit Saudi Arabia and Jordan in November of 1973 to remind the kings of their solid friendship with "Free China." Promises of expanding bilateral trade and technical cooperation programs were agreed upon in exchange for the kingdoms’ stable diplomatic support and export of crudes.[122] The last chapter mentioned that Taiwan's oil refining business was revamped by importing Kuwait, Iran, and Arabian crude. Since 1970, Saudi Arabian crudes had claimed almost half of Taiwan’s total oil imports along with Kuwait crudes and became the

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[122] "臺灣新生報底片民國六十二年（十八）[Taiwan Shin Sheng Daily films in 1973 (18)]" *台灣新生報 [Taiwan Shin Sheng Daily News]*, Academia Historica Collection, no. 1500312000018042, Academia Historica.

primary import source after 1981.[123] Such growing shares of Saudi Arabian crudes suggest that Sun's trip was in some sense a success.[124]

For TPC's part, as Chu commented in 1987, "the technical cooperation between the Kingdom of Saudi Arabia and the ROC in the field of electric power engineering has been by far the most extensive technical assistance Taipower has ever extended to a foreign nation."[125] Unlike TPC's other services as advisors or providing local personnel training in South Vietnam (1964-1975), Nigeria (1964-1966), or Honduras (during the 1970s and 1980s), the Al Baha project granted by the Saudi government in 1977 was TPC's first overseas project contract which included the construction of a power plant, transmission, and distribution lines to cover the power usage of a total of 22,000 households. Approximately 270 TPC personnel were sent to the site and worked overtime to earn the Saudi government's trust and their recognition of ROC.[126]

While sustaining fuel oil in its system during the 1970s, TPC also increased its coal storage capacity to deal with changing oil prices. Since 1969, the government also allowed TPC to conduct foreign trades for coal by itself. Before then, TPC procured 122,204 metric tons of foreign coal in 1968 through PCAC's arrangement, and a decade later, the amount rose to 1 million metric tons. While the government demanded that TPC maintain the procurement contracts with domestic coal mines for 600 to 700 thousand tons per year, TPC obtained more foreign coal at a lower price through long-term and spot-based contracts directly with the coal mine owners in the US, Canada, Australia, and South Africa. In Canada, TPC even co-invested in establishing Denthern Resources Ltd. with Denthern, Charbennages de France, and Denimil Energie and Mineral LG to exploit the coal deposit in Coalspur, Alberta in 1981.

Aside from criteria based on mining conditions such as coal quality and location proximity, TPC chose its trading partners with an eye on Taiwan's delicate political situation. After pouring investments into foreign mining or fuel trades, Chu Shu-lin, then TPC's manager, received a

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[123] Tien-chen Chou, "臺灣地區對國際能源情勢肆應之策略 [Taiwan's Strategy toward Global Energy Situations]," [Taiwan's strategy toward the global energy situations.] *Quarterly Journal of Bank of Taiwan* 38, no. 3 (1987): 399-435.

[124] In the context of Cold War and diplomatic race with the PRC, Taiwan’s international cooperation program was first launched in 1959 by sending agricultural assistance group to Saigon (now known as Ho Chi Minh City) in Vietnam and followed by projects in Africa and Latin America to win over the supports from those newly established countries in the 1960s for ROC’s seat in the UN. Facing the escalating diplomatic crisis in the 1970s, these programs reached further to Asia-Pacific regions under direct instructions from the Ministry of Foreign Affairs established the Committee of International Technical Cooperation. Financial supports by leasing loans were oversaw by the International Cooperation Department of MOEA since 1989. Later, the two government agencies integrated into the current International Cooperation and Development Fund in 1996 to continue Taiwanese government’s efforts in sustaining its international network.

[125] Chu, *Power Development in a Developing Country: Experience with Taipower (1946-1985)*.

[126] "Friendship of Trust of Sincerity," *Taiwan Today*, July 1 1979, https://taiwantoday.tw/news.php?unit=4&post=5114.

letter from the Ministry of Foreign Affairs in 1985 about their future investment decisions.[127] TPC was requested to inform the ministry in advance so that the government could use economic relations as diplomatic leverage. This suggests that losing the UN seat had severely undermined the KMT's legitimacy. The public relations efforts in sustaining international relationships were then channeled toward foreign investments, technical assistance, exchange programs such as the Al Baha project, and fuel trades since the 1970s. While working in line with the state's aim in the 1970s-1980s, TPC obtained more agency to venture further with their business relationships across the globe to acquire fuels and learn about nascent energy technologies. Yet, on the other hand, Taiwan's precarious diplomatic position also limited its fuel options, such as the nuclear materials needed when TPC began the design phase of its first nuclear power plant in the early 1970s.

Like oil, uranium was rendered a high-profile strategic material. Exporting countries would only consent to provide nuclear supplies on the condition of a bilateral agreement and the safeguards agreement with the IAEA. Even though American support was crucial for Taiwan to work toward such agreements, TPC also endeavored to develop its connections with overseas utilities and institutions to overcome Taiwan's lack of diplomatic recognition. For example, TPC established ties with the state-run Korean Power Engineering Company (KOPEC) after the Korean War. TPC staff were invited to visit KOPEC in 1962 and 1968 to provide advice regarding asset revaluation and their Ten-year Power Development Plan.[128] Later, TPC, KOPEC, and the American Anschutz Corporation cooperated through a joint venture in uranium mining, the Oviedo Project, in Paraguay between 1976 and 1983.[129]

In short, from TPC's viewpoint, they faced a complicated picture from the beginning of the 1970s. Fluctuating oil prices justified their plans to simultaneously increase coal and fuel oil inventories while accelerating the construction of nuclear power plants. Such integration

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[127] "公營企業向國外採購、投資時先知會外交部 [Public enterprises shall notify the Ministry of Foreign Affairs before purchasing or investing abroad.]" *經濟部 [MOEA]*, Academia Historica Collection, no. 0310704000004, Academia Historica.

[128] Taking TPC as a learning model for the just-established KEPCO makes sense in several aspects. First, the similarity in terms of their colonial pasts resulted in the same hydro-based power system designed to support the polarized military-industrial complexes in North Korea and Kaohsiung in Taiwan, respectively. Second, after 1945, the continued warfare had reshaped their power landscape, and both turned to US aid and foreign capital to re-boost their economy by increasing the capacity of hydropower and coal-fired plants. The formation of carbon-intensive infrasystems could be found in South Korea as well. Yet, TPC has a more extended history as a single public utility and an integrated system builder, while KEPCO was put into place by merging three private utilities in 1961 with the national aim of developing "indigenous" talents and technologies. The TPC also shared this goal in terms of "Sinofication" in response to the growing reliance on foreign technical assistance; only the TPC has been able to start earlier than KEPCO. The shared historical background, characteristics of power systems, and their common goal in the early 1960s became the foundation for their further cooperation in the following decades. For the visiting details in the 1960s, see, for example, Shu-lin Chu, "韓國十年電源開發方案," [South Korea's ten-year power development plan.] *Monthly Journal of Taipower's Engineering*, no. 240 (1968): 17-24.

[129] BOM, *Minerals Yearbook 1980 Volume III*, The US Bureau of Mine (Washington: U.S. Government, 1982).

with the fuel mining, storing, and shipping business led TPC to widen the scope of both its investments and its integrated infrasystem. Along with the expansion of TPC's fuel network, its engineers' local networks were also extended to link up the infrasystems, in which the Chinese Institute of Engineers (CIE)’s intermediate role was essential.

CIE had a long relationship with the KMT government before the Chinese Civil War. It was a nonprofit organization established in Kuang Chou in 1917 by a group of engineers studying in the US that shared the same devotion to building a modern China.[130] Since its office was relocated to Taiwan in 1951, it has represented the hub of Taiwan's most influential engineers and technocratic figures. From Ministers of Economic Affairs, Ministers of Transportation, and Presidents of the nationalized enterprises (including TPC, CPC, Taiwan Sugar Company, and China Steel Corporation) to the Chief Engineer of Kaohsiung Harbour Bureau, CIE provided the platform for engineers across fields to exchange information and extend their networks. In turn, it functioned as the breeding ground for further cooperation.

Among the subsequently reinvested corporations, Sinotech Engineering Consultants Inc., founded in 1970 by the Ministry of Economic Affairs, TPC, CPC, CIE, and ten other public agencies and private-owned companies, is a case in point. The then TPC assistant manager, Gu Wen-kui, was appointed by the Ministry of Economic Affairs to convene its establishment. In 1979, Sinotech Engineering Consultants Inc. joined Gibbs & Hill, Inc. to set up Gibsin Engineer, Ltd. (GEL) and Pacific Engineers & Consultors, Ltd. (PECL) with Bechtel. GEL became Taiwan's only consultant company capable of designing large-scale conventional thermal power plants. As for PECL, its main task was designing, managing, and commissioning TPC's fourth nuclear power plant. Later, these two companies built TPC's power plants and fuel transport facilities, including coal yards, coal unloading terminals, and liquefied natural gas receiving terminals.

Their emergence by the end of the 1970s was aligned with TPC's diversification of its power units and fuel network. Domestic coal was loaded on trucks and delivered to TPC's Northern coal yards, including the Badouzi Branch and Shen-ao Branch in Keelung along the rails, and the Linkou coal yard to support the nearby thermal power plants in northern Taiwan. As for foreign coal, it implied the same need as fuel oil did to proliferate the shipping and storage capacity within thermal power plants. The fuel system further shows the interdependence of the CPC and TPC systems. Aside from expanding existing coal yards and building new ones, in 1979 TPC scheduled construction of three more coal unloading ports in southern, central, and northern Taiwan, respectively, all due to begin operation by 1990. With its exclusive coal receiving terminal, Taichung thermal power plant was planned to function as another baseload plant in the central region to balance the polarized power supply system. It is important to note that, except for the shallow draft Hsinta port in Kaohsiung (which relied on the transshipment of the southern Talin coal terminal), other terminals, Taichung and Su-

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[130] Ya-chun Chang, "The Chinese Institute of Engineers in post-war Taiwan: The close yet remote relations between the state and engineers" (Master Thesis, National Taiwan University, 2014).

au, were possible because they were located at the wharves of the developing harbors under the aforementioned Ten Major Construction Projects. Otherwise, TPC would not have had the power and budget to mobilize the local government and harbor bureaus.

In sum, by the early 1970s, the carbon-intensive network was not harmed but intensified by the multiple crises. Instead, they raised energy issues to a national security level and triggered the KMT government's attempt to mitigate the subsequent economic and political instability by launching large public infrastructure projects. Therefore, the power system’s physical and spatial scale had risen to integrate coal yards, coal bunkers, coal receiving terminals, coal rails, oil storage tanks, and pipelines in Kaohsiung and across regions. This emerging fuel network during the 1970s and 1980s reshaped the island's coastlines and fishing villages. With hindsight, as the interlinked CPC and TPC systems extended across regions to deal with the geopolitical oil crisis, they soon found themselves entangled with domestic power struggles. In order to understand how the public backlash against the infrasystems and the subsequent political debates substantially rearranged the power relations of Taiwan's energy politics, it is essential first to recognize the impacts of the proliferation of fuel storage and transport capacity, which triggered TPC to rethink its operational logic, especially after the second energy crisis of 1979.

3.2.2 The second oil crisis in 1979: Dealing with surplus

The second oil crisis's impact on TPC's coal business differed significantly from the first. CPC's records show that the cost per barrel of oil in USD rose from $7.67 in 1974 to $28.55 in 1980.[131] The government put a price ceiling on staple merchandise after 1973 to reflect the actual cost of products and caused the inflation rate to surge to 40.6 percent in the next year. On close inspection, the oil price adjustment was lower than the amount of the global crude oil price hike. The government's lower import tax and CPC's loss absorbed the price differences. However, the second oil shock forced the government to introduce an official price-determining mechanism into the market to lessen CPC's financial burden. In turn, TPC's fuel oil operational cost rose three times much.[132] On the national scale, the ensuing global economic recessions led to the drop of Taiwan's economic growth rate from 8.1 in 1979 to 3.76 percent in 1982, and its severity directly affected TPC's electric consumption growth rate from 10.1 in 1979 to -1.4 percent in 1981.[133]

Accordingly, in order to alleviate the industries’ burden of the mounting manufacturing cost, the government instructed TPC to cut down the agreed purchasing capacity in the original power procurement contract with those industries. TPC's revenue, therefore, decreased as

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[131] Chou, "臺灣地區對國際能源情勢肆應之策略 [Taiwan's Strategy toward Global Energy Situations]."

[132] Tzong-shian Yu and Chin-lih Wang, *一隻看得見的手: 政府在發展過程中的角色* [A Visible Hand: Government's Role in the Development], 台灣經濟發展論文集, (Linking Publishing Co., 2003), 393.

[133] Chou, "臺灣地區對國際能源情勢肆應之策略 [Taiwan's Strategy toward Global Energy Situations]."

well. The heavy financial burden forced TPC to postpone the construction of two coal receiving terminals and halted its cross-border mining business, including dropping out of another 25-year coal mining contract at the Bowron River Coalfield in Canada with Norco Resource Ltd. of Vancouver.[134]

Another policy measure was implemented in 1980 to mitigate the second crisis's impact on Taiwan's carbon-intensive network. Among private corporations, the cement industry was one of the most significant coal consumers. Their total coal consumption increased from 240 thousand tons in 1961 to 730 thousand tons in 1967.[135] When TPC shifted to fuel oil for its lower price in the late 1960s, those cement manufacturers took the same leap by abandoning domestic coal. The hiatus continued until the government requested all cement plants change back to coal by 1983. In so doing, their demand for coal surged to 2.1 million tons in the same year, while TPC's coal demand went up to 3.1 million in 1982. The amount seems overwhelming at first glance, but TPC's coal inventory was even higher. In early 1980, TPC ramped up the safety stock of coal from 3 to 5 months and oil inventory from 30 to 90 days. According to TPC's procurement contracts for foreign coal, the assumed amount was 3.01 million tons in 1982, while their coal yards had reached their saturated storage capacity. The over-supply situation was the first time TPC was forced to confront its cumbersome system with significant excess and obsolete fuel stocks and power units.

TPC's strategies can be broken down into three parts. First, with respect to coal supply, in order to deal with the excess coal stock TPC negotiated with the foreign mine owners to revise the agreement. For example, before TPC withdrew from the Bowron River Coal project, it only adjusted the contract amount and reduced its investment to half in 1982. A few years later, TPC cut down 20 percent of all their 1986 contracted amount and adjusted the regulation of the safety stock of coal and oil back to the original pre-1979 level.[136] Second, regarding baseload electricity supply, it was determined to add more nuclear units into the system. Thirdly, from the side of electricity load control, TPC adjusted the price structure to promote off-peak power usage to increase its load factor. In short, TPC wanted to continue the plans for expansion of its fuel network to keep the fuels interchangeable and available for its system. Yet, such operational logic resulted in the fuel system's overcapacity.

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[134] A report conducted by the Norco Resource Ltd. addressed TPC’s involvement in the beginning. See Norco, *Summary of the Bowron River Coal Project* (1983). Their cooperation with the TPC was thought as additional achievement while the British Columbian officials was simultaneously looking for consumers especially from Japan and Korea in the late 1970s. See Frank Langdon, *The Politics of Canadian-Japanese Economic Relations, 1952-1983* (UBC Press, 1983), 180.

[135] "礦務局檢陳「臺灣煤炭市場現況與今後採取之措施」簡報資料 [Bureau of Mines reviews briefing materials on "Current Situation of Taiwan's Coal Market and Future Measures"]" *臺灣省政府委員會議 [Taiwan Provincial Government Committee Meeting]*, Taiwan Historica Collection, no. 00502064806, Taiwan Historica.

[136] "紓解存煤壓力 [Relieve pressure on coal storage]" *經濟部 [MOEA]*, Academia Historica Collection, no. 0310704000060, Academia Historica.

The TPC in-house discussions through journal articles and department meetings since the 1960s suggest that this was a long-existing issue with TPC's concentration on expanding baseload plants. Before the nuclear units were introduced to the system, the discussions were centered on the optimal coordination between run-of-river units, impoundment facilities, coal-fired or fuel oil-fired steam turbines, and gas turbines. For example, at the CIE conference in November 1961, one of the symposiums moderated by the TPC's assistant manager, Sun Yun-suan, was about thermal power technology. They invited G. R. Hahn from Gibbs & Hill to share how to decide on steam turbines' operation and derating timing with different heat efficiency.[137] When the first nuclear unit rated 636 MWe was connected to the grid in 1977, it coordinated with fuel oil-fired units to run 24 hours for constant output. However, nuclear power's installed capacity soon multiplied to 5,144 MW, exceeding the 4,932 MW of oil-fired units by 1985. Fuel oil-fired units were forced to derate or stand by as their operational costs exceeded nuclear power. To deal with the residual power generated during off-peak hours, pumped-storage units were integrated into the system in 1985. At night, these absorbed the residual energy to pump water from the lower elevation of the reservoir to the higher elevation of the Sun-Moon-Lake reservoir to prepare for supporting peak load the next day.

In other words, the operational logic did not change. TPC's response regarding energy diversification focused on fuel flexibility but not systemic flexibility. From 1979 to 1985, only nuclear units reduced TPC's fuel oil usage, but fuel oil remained the supplementary power source in case the nuclear units were overhauled.[138] The lack of peak load plants and fast start-up units, such as power generators with hydraulic turbines or gas turbines, made it vulnerable to any malfunctions of its large-capacity conventional units, and it was challenging to find alternatives. In other words, the reason the second oil crisis had a much greater impact on the TPC system was TPC's decision to sustain its costly and baseload-oriented expansion mode by adding new nuclear power units. Although TPC justified its decision to develop nuclear power as a way to mitigate its oil dependency, the next section will elaborate on the different expectations toward nuclear technology from a historical review of Taiwan's atomic power development since the mid-1950s. What did building a nuclear power plant on the island entail for the state and the TPC system? Were nuclear power units actually intended as an alternative to fuel oil and a solution to the oil crisis?

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[137] Hong-qian Wu, "火力電廠尖峰運轉問題," [The operational issues of thermal power plant at peak hours.] *Monthly Journal of Taipower's Engineering*, no. 161 (1962): 1-8.

[138] Fuel oil’s continuation in the 1980s could be seen from the record stating CPC's complaints about TPC's changing demand that caused troubles for their sales and operation planning. "臺電公司燃料油及天然氣採購計畫 [Taipower Company’s fuel oil and natural gas procurement plan]" *經濟部 [MOEA]*, Academia Historica Collection, no. 0310704000108, Academia Historica.

3.3 The proliferation of carbon-intensive infrasystems with nuclear power units

TPC spent eight years (1971-1979) bringing its first two nuclear power units online. Yet the 1978 opening was in fact preceded by a much longer process over almost two decades of gaining the required foundational knowledge in nuclear engineering. Two years after US President Eisenhower's Atoms for Peace speech in 1953, Taiwan's nuclear energy governance agency, the Atomic Energy Council (AEC), was established at the ministerial level under the Executive Yuan. The first task of Taiwan’s AEC was to work on the agreement for cooperation between ROC and the US to obtain nuclear reactors, materials, and information for research purposes. Based on America's support, ROC was listed as a founding member of the International Atomic Energy Agency (IAEA) in 1957. In this context, Taiwan's nuclear journey began with the arrival of its first Open Pool Reactor for experiments and personnel training at the relocated Tsing Hua University (from Beijing, to Kunming, and finally in Hsinchu) in 1958.

Considering the required space and money for the research reactor, the government paid for the university’s atomic research center from the Tsing Hua Fund, which originated from the returned surplus of American money – the so-called Boxer Indemnity stemming from the 1901 Boxer Rebellion – that flowed to Taiwan but not the PRC.[139] The first head of the Tsing Hua atomic research institute was Sun Guan-han, who received a Boxer Indemnity Scholarship and obtained a doctoral degree in physics at Pittsburgh University. His expertise and later experience in Westinghouse's nuclear science lab at Pittsburgh led Tsing Hua University to become the hub of Taiwanese nuclear scientists' international network.

However, it is important to note that the brain drain was severe due to the domestic political situation, relatively limited research funds, and poor salary conditions in Taiwan's academies. Even though atomic power research was one of the few research fields to which the KMT government devoted most of its efforts since the 1950s, the talent shortage remained a problem. For example, Sun only stayed in Tsing Hua for a year as a visiting professor while holding a concurrent post as the director of the atomic research lab. It had to wait until the late 1960s when the U.S. advisors finally convinced the Taiwanese bureaucrats to increase R&D investments to integrate basic and applied scientific research to advance Taiwan's industrial

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[139] After the Boxer Rebellion in 1899 upraised against the foreign countries’ influences on mainland China, the Eight-Nation Alliances carried out invasions in response the next year. The following agreements, Boxer Indemnities, were put down in 1901 between the Chinese Emperor and foreign powers, including the United States. Seven years later, the US Congress agreed to direct the excessed compensations to financing the Chinese educational programs and particularly students’ school admissions in the United States, as known as the American Boxer Indemnity Scholarship Program. Tsing Hua University’s establishment using the fund was a critical node of the network. For more about the American boxer indemnity, see Xiao-juan Zhou, "The influences of the American boxer indemnity reparations remissions on Chinese higher education," (2014); Peng-xiu Sun, "A Study of the American Boxer Indemnity Scholarship Program and its Influence on Chinese Education: Taking Shandong Students as an Example" (Master thesis, Seton Hall University, 2019); Michael H. Hunt, "The American remission of the Boxer indemnity: A reappraisal," *The Journal of Asian Studies* 31, no. 3 (1972): 539-59.

development.[140] In this sense, Taiwan was late compared to its neighboring countries; Japan, in particular, had enacted its Atomic Energy Basic Act in 1955 and targeted building a nuclear industry through the alliance of the four major Japanese enterprise groups, including Mitsubishi, Mitsui, Sumitomo, and Furukawa, that has covered the metal, heavy chemicals, banking, electrical engineering, and electricity industries ever since.[141] Taiwan's Institute of Nuclear Research under the AEC only came into being in 1968 to formulate a comprehensive nuclear research plan and the Atomic Energy Law. How, then, should we explain Taiwan's delay in initiating both its nuclear policy framework and programs?

According to a review report written by the Director of the AEC, Huang Ji-lu, in 1965, AEC's organizational scale and limited budget were the causes of the lack of long-term development projects. "AEC is the decision-making organization for nuclear policy, but the staffing remained the same at five staff since the AEC's foundation, which makes it hard to carry out nuclear activities." He continued with the problems of AEC's annual budget of only NTD$200 thousand compared to large national investments in latecomer countries such as Thailand, South Korea, and the Philippines.[142] AEC's function before 1968 was mainly administrative, dealing with affairs such as international contacts and approving scholarship applications for sending graduates abroad for relative training. More importantly, Huang urged the government to enable TPC to work independently in arranging nuclear power plant designs, international loans, and transnational technical cooperation, among his corresponding suggestions. TPC's limited authority in mobilizing resources to facilitate its own nuclear program also explained the nuclear power plant's emergence in the late 1970s rather than the 1960s.

Although TPC set up its atomic power research committee and started a special column for atom power in the *Monthly Journal of Taipower Engineering* as early as 1955, the materialization of its nuclear program still significantly depended on the state's bureaucratic support. The following year, TPC soon began contacts with the Westinghouse Electric Co. to purchase a pressurized water reactor rated at 15 MWe even if the needed fissionable materials would still depend on the Ministry of Foreign Affairs efforts to add an article to the existing ROC-US bilateral agreement permitting import of such materials.[143] When Sun Yun-suan was

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[140] J. Megan Greene, *The Origins of the Developmental State in Taiwan: Science Policy and the Quest for Modernization* (Harvard University Press, 2009), 238.

[141] "日本之原子能和平用途 [Peaceful uses of atomic energy in Japan]" *行政院原子能委員會會議紀錄及有關文件 [Minutes and related documents of the Atomic Energy Council of the Executive Yuan]*, Academia Historica Collection, no. 020000022171A, Academia Historica.

[142] "增進我國原子能積極發展之初步計畫 [Preliminary plan to promote the positive development of atomic energy in our country]" *褒揚史料 [Praising historical materials]*, Academia Historica Collection, no. 1550740060026A, Academia Historica.

[143] "原子能委員會第十一次會議紀錄 [Minutes of the eleventh meeting of the Atomic Energy Council]" *行政院原子能委員會會議紀錄及有關文件 [Minutes and related documents of the Atomic Energy Council of the Executive Yuan]*, Academia Historica Collection, no. 020000022171A, Academia Historica.

still in post as TPC's chief engineer, he tried to gain the AEC's backing to persuade the Ministry of Economic Affairs for their approval. Sun explained that "it could firstly help us to learn the experience and operational methods of nuclear power in a short time; Second, we could use the reactor to train our domestic talents." The chair of AEC, Li Hsi-mou's instant support echoed Sun's proposal considering the nuclear contest between the ROC and PRC at the time, "last year in the Geneva Conference, the Soviets declared to help the PRC to build a nuclear power plant with the capacity of 6.5 MW and gave them a particle accelerator. If Taiwan could utilize nuclear power for electricity generation as soon as possible, it would be a major blow to the PRC in terms of political propaganda." [144] Nevertheless, since the economic rehabilitation projects relying on US aid only started in the 1950s, the KMT government did not consent to the costly and small-scale nuclear power reactor. What turned the mindset was the escalating tension with the PRC in the ensuing decade.

Developing nuclear science became one means to achieve ROC's (and also PRC's) ultimate goal of reunification by force. Since 1964, PRC launched numerous nuclear tests that threatened Taiwan's national security, which became one of the AEC's main discourses to accelerate the national development of nuclear science. Meanwhile, as carbon-intensive users became the primary foreign exchange earners in the late 1960s, the attraction for developing nuclear power became its capacity to meet industrial power demand. Based on that premise, TPC was granted more agency in procuring foreign fuels and obtaining international loans. In so doing, TPC was also able to build its nuclear power plant. As mentioned in the previous chapter, in the long run, nuclear power was rendered an additional energy carrier in Taiwan's first energy policy of 1968. In the TPC system, nuclear power's priority and position changed accordingly from an innovative energy technology in the 1950s to a critical element to sustain its thermal power-based system.

TPC's consideration of the scale of nuclear power reactors varied in terms of its economic feasibility and systemic adaptability in different scenarios. In the beginning, Sun's proposal to build a 15Mwe or, later, a 20Mwe nuclear power reactor when the IAEA visited Taiwan in 1959 was mainly for training or testing.[145] Into the 1960s, nuclear power technology began to carry the hope of tackling the coal problem. Deng Guang-sin, a TPC engineer who received the IAEA sponsorship of nuclear reactor engineering and received training in the US in 1958, wrote an

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[144] "原子能委員會第七次會議紀錄 [Minutes of the seventh meeting of the Atomic Energy Commission]" *行政院原子能委員會會議紀錄及有關文件 [Minutes and related documents of the Atomic Energy Council of the Executive Yuan]*, Academia Historica Collection, no. 020000022171A, Academia Historica.

[145] In 1959, the IAEA sent a visiting group of six experts in training, industrial economy, reactor, medical, agriculture, and nuclear fuel to Taiwan to discuss nuclear power's technical and operational coordination. Japan, the Philippines, Korea, and Vietnam were also on their tour list. See John DiMoia, "Atoms for sale?: Cold War institution-building and the South Korean atomic energy project, 1945–1965," *Technology and Culture* 51, no. 3 (2010): 589-618. Chen-hua Chen, "國際原子能總署初步技術協調訪問團給我們帶來了什麼?," [What did the IAEA technical communication group bring to us?] *Monthly Journal of Taipower's Engineering*, no. 131 (1959): Inside front cover.

article in 1961 titled *Taiwan's First Nuclear Power Plant's Capacity and Site Selection.*[146] The paper first pointed out TPC's possible increasing operational cost in the scenario of the possible domestic coal shortage. Nuclear power was seen as the solution to help cover the baseload in line with TPC's expanding agenda. Its technical features fit well with such an application. Considering nuclear power's inflexibility to rapidly ramp up and down to avoid possible damages from regular voltage changes, and the fact that it would need a longer time to cool down and restart than conventional turbines, nuclear power units often run 24/7 at full capacity in most countries. For Deng and other TPC engineers in the planning division, if the large-capacity nuclear power unit was added to the system, TPC needed to enlarge or build more thermal power units to serve as the systemic reserve margin. Theoretically, a power system's reserve margin is set to be the amount of the largest power unit to tackle any power cut due to an emergency shutdown or annual maintenance of power plants. Depending on the different load forecasts, it could also be 10 to 20 percent of the total installed capacity. For the TPC system, TPC assumed that its total capacity would reach 2,078.8 MW with new units installed at the Nanpu power plant (125MW) and the completion of the Shen-ao thermal power plant (125MW) by 1968. Thus, the first nuclear power unit should rate at 200 or 225 Mwe claiming around 10 percent of system capacity and fitting in the expected thermal units' combined coverage.[147]

Deng's later article in 1967 shows how TPC's growing expectation toward nuclear power's ability to support growing industrial power demand. One year earlier, the concurrent Hong Kong 1967 leftist riots (a part of the Cultural Revolution instigated by the founder of the PRC, Mao Tse-tong) had pushed more industries based in Hong Kong to flee to Taiwan. Deng then adjusted to a 500 Mwe design (the same as the TPC standardized design of coal- or fuel oil-fired steam generators) to maintain the momentum of system expansion to support rising industrial demand.[148] TPC's estimation of the nuclear unit's capacity multiplied in accordance with upgrading steam turbines.

In short, nuclear power units were not a substitution but co-evolved with TPC's thermal power-based system. TPC's Ten-year Development Plan (1966-1975) made nuclear power plants central along with expansion projects to increase the power units of large-scale steam

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[146] Guang-sin Deng, "臺灣第一座核能電廠容量與廠址之選擇," [Taiwan's first nuclear power plant's capacity and site selection.] *Monthly Journal of Taipower's Engineering*, no. 152 (1961): 55-72.

[147] A cap of 10 percent was a rule of thumb for isolated electricity systems in the 1960s and 1970s. For example, Ireland's isolated power grid was initially fed mainly by hydropower plants in the early 1960s, but the increasing coal/oil stations contributed its growing oil dependency to 60 percent by the early 1970s. The subsequent introduction of nuclear power into its system followed the principle as well. See Maurice Manning and Moore McDowell, *Electricity Supply in Ireland: The History of the ESB* (Gill & MacMillan, 1984).

[148] Guang-sin Deng, "台電核能發電之展望," [The prospect of Taiwan's nuclear power development.] *Monthly Journal of Taipower's Engineering*, no. 226 (1967).

and gas turbines for low-capital cost.[149] It required supporting facilities for unloading large components, fuel transportation, cooling water supply, and extra-high voltage transmission lines – all of which fit well into the existing infrasystems network of the TPC system. In other words, TPC's load-following and densified expansion mode did not need to adjust too much in adapting to the new nuclear element.[150]

The process of site selection also worked to dovetail nuclear power with TPC's existing infrasystems. After inviting IAEA's experts to assess the potential sites in 1966 and 1968, they advised that the future nuclear power plants should locate in coastal areas to have better access to the cooling water but close to the load centers in southern and northern Taiwan to reduce power loss. Assured by IAEA, TPC's power development division and the American Bechtel Corp. delivered a feasibility report on TPC's nuclear power plants in 1969 to get a $70 million loan from the Export-Import Bank of the United States for constructing its first nuclear power unit. They were of the opinion that to meet the power demand in northern Taiwan in 1975, installing a nuclear unit rated at 636 MWe at Jinshan was a more economical option than installing another oil-fired thermal power unit rated at 500 MW in the Linko plant.[151] Nevertheless, Linko still had its two coal- and oil-fired units rated at 300 MW per unit installed in the following years. Furthermore, because of the delayed delivery of its second steam turbine, 13 gas turbines were placed in the Linko plant in case an emergency power backup was needed.

The conventional explanation for the emergence of nuclear power in the late 1970s often refers to its contribution to Taiwan's increasing energy independence from fossil fuels.[152] This section explained how TPC decided to remain highly dependent on oil, coal, and nuclear, and how these fuels supplemented each other in the TPC system over time. As the TPC system evolved, the major change that nuclear units brought was shifting the oil-fired steam turbines to support peak loads and bringing pumped-storage hydropower units to the system to deal with the power surplus from nuclear power plants. When the electricity growth rate slowed in the mid-1980s, criticisms and doubts about the necessity of the TPC system's further

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[149] The long-range plan was revised when the first oil crisis of 1973 occurred. The plan was replaced by the new Six-year Development Plan scheduled from 1976 to 1981. The construction of TPC's first and second nuclear power plants were incorporated into both TPC's Six-year plan and the Ten Major Construction Projects which suggests that the first oil crisis was not the reason for TPC to build nuclear power plant.

[150] Nuclear power units fit well into the energy economy as "business-as-usual" by sustaining the costive and concentrated power system. See Lan-gao Chen, "開發電源的新境界," [A new stage of power development.] *Monthly Journal of Taipower's Engineering*, no. 329 (1976): Inside front cover. Aviel Verbruggen, "Renewable and nuclear power: A common future?," *Energy Policy* 36, no. 11 (2008): 4036-47.

[151] TPC, "北部核一廠工程概要（一）," [An overview of the construction works of the first nuclear power plant.] *Monthly Journal of Taipower's Engineering*, no. 298 (1973): Inside front page.

[152] The justification for Taiwan's nuclear power development often stems from the idea of fearing too much dependency on imported fossil fuels or as one of the results of the U.S. influence. See for example, Shu-hsiang Hsu, "Advocacy coalitions and policy change on nuclear power utilization in Taiwan," *The Social Science Journal* 42, no. 2 (2005): 215-29.

expansion arose. The combined political and energy crisis engendered Taiwan's first-ever negative economic performance since 1954 that hindered both TPC's fuel network and the KMT's authoritarian rule. Concurrent nuclear incidents such as the ones at Three Mile Island in 1979 and Chernobyl in 1986 and local process accidents of TPC's nuclear stations during the 1980s raised public concerns about the nuclear safety issues in Taiwan and triggered the emergence of large-scale democratic and environmental movements. The social upheaval that entangled with energy issues in this period signaled the watershed moment from which would emerge Taiwan's divergent party politics and the debates on the optimal energy mix (revolving around pro-nuclear versus anti-nuclear positions) in the following decades.

3.4 When TPC's power scenario converged with the 1980s' political reality

As the TPC system kept expanding through the 1970s and 1980s, three nuclear power plants were completed in northern and southern Taiwan in proximity to the load centers. Challenges against TPC's carbon-intensive networks emerged in the mid-1980s, along with Taiwan's gradual democratization. Before KMT lifted Martial Law in 1987, the party-state exerted strict limitations on speech, publication, and organizational freedom that helped prevent local protests against the externalities of the TPC system turning into a large-scale social movement. Yet, as the authoritarian regime loosened, TPC's highly polluted thermal power-based system with the expanding nuclear power stations provoked the alliance of the major opposition political party, DPP, with NGOs and grassroots organizations that all identified the KMT government as the common culprit. Phasing out nuclear power in Taiwan was even listed as one of the goals in the DPP's party manifesto. For instance, the construction of TPC's fourth nuclear power plant was delayed due to continuing protests at the site location in Gongliao township. The frequent malfunctions that triggered the reactors in TPC's third nuclear stations to stop drew the public's attention to nuclear issues.[153] Unable to clear up the doubts, in 1985, the then Prime Minister announced in a cabinet meeting that construction would be halted until the public could "better understand" the safety and functioning of nuclear power.[154] From a systemic perspective, even though scholars often portray Taiwan's anti-nuclear movements since the 1980s as a public outcry over the energy decision made under the KMT's authoritarian regime and mostly grown out of "safety concerns" and unjust

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[153] "臺電公司七十四年度工作考核應行檢討改進事項 [Taipower Company's 74th annual work assessment that should be reviewed and improved]" *經濟部 [MOEA]*, Academia Historica Collection, no. 031070400090, Academia Historica. According to the TPC's survey on people's acceptance and knowledge for nuclear power plants in 1983 and 1986, 43 percent of the interviewees expressed no awareness of the existence of nuclear power plants in Taiwan. After the fire accident broke out at the third nuclear station in 1983 following a series of protests against FNPP, the number increased to 80.7 percent in 1986. See Christian Schafferer, "Taiwan's nuclear policy and anti-nuclear movement," *Understanding Modern Taiwan: Essays in Economics, Politics and Social Policy* (2001): 97-125.

[154] "行政院會議議事錄 臺第五七八冊一九三一至一九三四 [Proceedings of the Executive Yuan meeting, Volume 578, 1931-1934]" *行政院 [Executive Yuan]*, Academia Historica Collection, no. 0140002050060 5002, Academia Historica.

site selections. I argue that (as the failure of TPC's Su-ao thermal power plant in Yilan County indicates) doubts were raised more about TPC's vision of an ideal energy mix and its expansion logic at large.

Building the Su-ao power plant was as crucial for the TPC system as for the KMT government. It represents an additional large-capacity baseload power plant to support the load center in northern Taiwan. However, the plant's scale also increased due to the overwhelming protests with various requests for compensation and environmental protection measures. The construction budget was increased from around NTD$6.4 billion in 1981 to NTD$ 141.3 billion in 1992, and thus, the Su-ao project was rendered another major national infrastructure project as the fourth nuclear power plant.[155]

In other words, as the story unfolds, it shows how the energy disputes were carried out across national and local government levels, entangled with complicated political and economic interests. The Su-ao event was the first-time people outside the TPC challenged its energy forecast and future power scenarios. By involving heterogeneous actors in debates, such as politicians (across governmental levels), residents, fishery communities, private petrochemical corporations (Formosa Plastics), wetland birds, and environmental organizations (Yilan Environmental Protection Union), it also reveals the various political and economic interests entangled within the TPC system since the 1980s. By looking into the case, this section discusses TPC's strategies in dealing with the challenges and developmental risks, which yield significant implications for Taiwan's later renewable transitions.

3.4.1 Before the storm: the penetration of the carbon-intensive network into Yilan County

Before TPC sought Yilan County as the next potential site for another thermal power plant, Yilan County had two run-of-river hydropower plants with a total installed capacity of 2.64 MW and one Cingshuei geothermal power plant demonstration site rated at 3MW, which was later shut down in 1993 due to the decreasing steam from its hot water wells. Therefore, without baseload power plants, Yilan County's electricity supply mostly relied on a 161 KV transmission line interconnected with Taipei City. Situating a thermal power plant in Yilan County could reduce power loss through long-distance transmission, but its function was more than this from TPC's perspective.

TPC set its eyes on coastal land of 245 hectares (almost as large as the nearby industrial parks that could house over 200 factories) starting from the northern part of Wuweigan to Beifangao at the Su-ao port to build a coal-fired thermal power station with four units rated at

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[155] Unknown, "台電編列六十四億預算規劃興建蘇澳燃煤電廠 [Taipower plans to build the Su-ao coal-fired power plant with a budget of $NTD6.4 billion]," *Economic Daily News* 1980; Eunice Wang and Zhen-lin Chiang, "台塑在利澤工業區二百八十公頃地近日公告強制收買 [Formosa Plastics recently announced the compulsory acquisition of 280 hectares of land in Lize Industrial Zone.]," *Economic Daily News* 1992.

50MW including a coal yard of two-phases construction (see Figure 11). In the meantime, the government granted construction permission to the fourth nuclear power plant in 1980, located at Gongliao Township in Taipei County. Based on TPC's estimation in 1979, the best situation would be for the first two units of Su-ao station to go online by 1986 in coordination with the Shen-ao coal-/oil-fired station rated at 400MW, which is also in Taipei County to support this northern load center while the fourth nuclear power plant would wait on the sideline supplying them with abundant baseload power sources.[156] To achieve such a goal, TPC first arranged its fuel logistics to keep the regional balance of supply and demand for coal. The construction of coal terminals at Taichung in central Taiwan, Hsinta, and Su-ao Port were all supposed to be completed by 1990.[157] They soon negotiated with the Su-ao Harbor Bureau to prioritize widening the main channel of the Su-ao port's extension program under the national Ten Major Construction Projects. It was expected to accommodate 60 thousand tons or 100 thousand tons of coal carriers for the needs of the Su-ao station. Not confining itself to waterways, TPC also asked TRA to assess the feasibility of an exclusive railway to tranship coal between Su-ao Port and Shen-ao station.

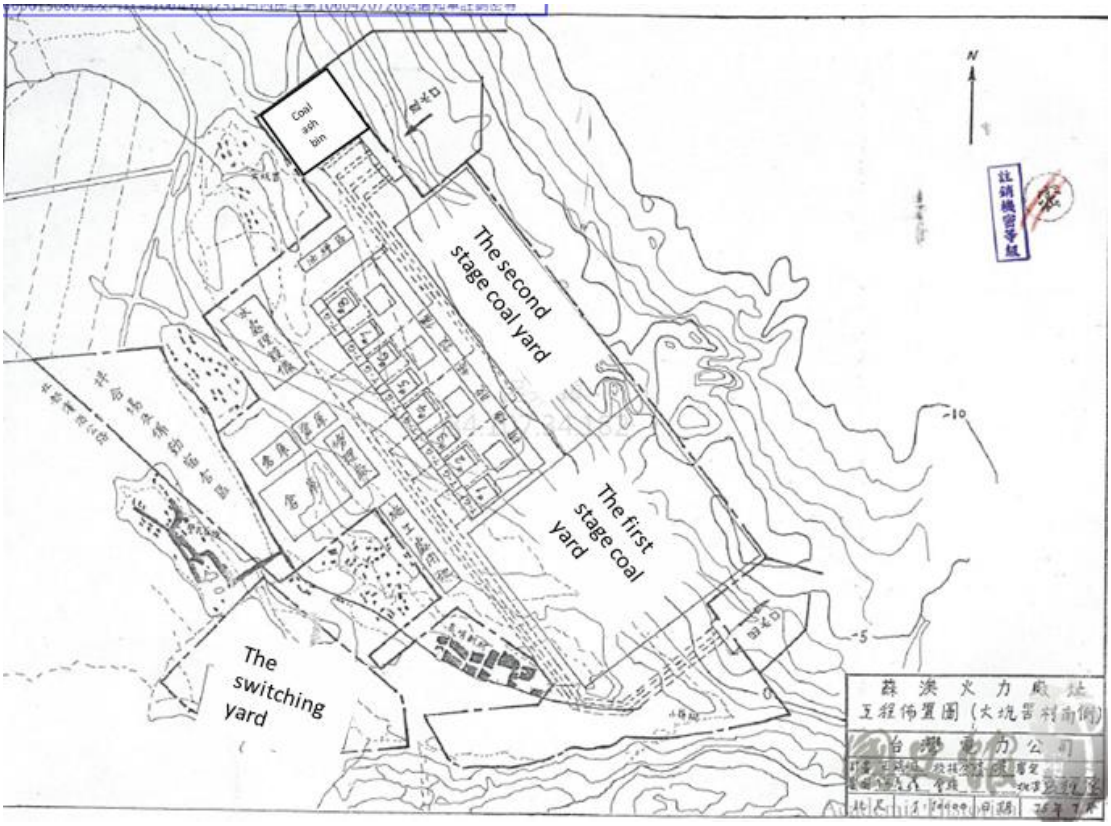

Figure 11 A diagram for constructing the Su-ao thermal power plant in 1986.

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[156] "臺灣地區能源政策執行情形 [Implementation of Taiwan's energy policy]" *經濟部 [MOEA]*, Academia Historica Collection, no. 0310704000114, Academia Historica.

[157] "臺灣地區能源政策執行情形 [Implementation of Taiwan's energy policy]", no.,

Source: Excerpted from 蘇澳火力發電計畫及廠址購地等[Su-ao thermal power generation project and plant site purchase, etc.]. (1986, June 17). 經濟部[MOEA] (0310704000130). Academia Historica Collection. Academia Historica. Page 18.

Meanwhile, another carbon-intensive user that would benefit from building the Su-ao coal terminal was Yilan's cement industry. Cement manufacturing had been the primary business in Su-ao Township since the Japanese colonial period. In 1994, the Taiwan Cement's Su-ao cement plant even claimed over half of the company's total production.[158] As mentioned in section 3.1, the government requested the cement manufacturers to shift back to coal by 1983, and their demand reached 2.1 million tons that year.[159] As a result, the Prime Minister directly authorized TPC to build its Su-ao coal terminal to support the demand for its power plants and sell and transport the imported coal to nearby industries.[160] Simultaneously, the Su-ao coal yard was established to start storing coal in advance.

Along with the growing productivity of the cement industry and the setup of two industrial parks adjacent to the Su-ao port, Loung-Te Park was finished at the end of 1978. Another Letzer Park construction work was launched in 1980. TPC's Su-ao project bore the hopes for bringing more industrial and infrastructural investments to Su-ao township and Yilan County. Especially for a county in eastern Taiwan, improvements to the relatively underdeveloped highways, ports, and electricity system were of great interest to the local economy, society, and politics.

Yet an interruption occurred as the electricity sales growth rate declined in 1981, making TPC revise down from 10 percent annually to 7 percent. In return, they had to reshuffle their long-range power development plan, including postponing the installation of the first two units of the Su-ao power plant and the required land acquisition procedures for the station site and coal terminal. Instead, TPC only focused on building the Taichung coal terminal in 1981. TPC's determination to extend its fuel network remained in place especially after the KMT government announced a major policy (re)turn toward oil-economy in 1984. Yu Kuo-Hwa, succeeding Sun's position, resolved to withhold the fourth nuclear power plant's construction and gave the petrochemical industry back its position as one of the national targeted industries. The following year, TPC picked up and redesigned its Su-ao project to cover the absence of the fourth nuclear power plant on its development agenda. Meanwhile, the deregulation of upstream petrochemical businesses began, allowing Formosa Plastics to build Taiwan's first privately-owned naphtha cracking plant, known as the sixth naphtha cracking plant, located at

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[158] Rui-jin Peng, *蘇澳鎮志* [The History of Suao Township] (Su-ao Township Office, Yilan County, 2013), 884.

[159] "礦務局檢陳「臺灣煤炭市場現況與今後採取之措施」簡報資料 [Bureau of Mines reviews briefing materials on "Current Situation of Taiwan's Coal Market and Future Measures"]", no.,

[160] "蘇澳火力發電計畫及廠址購地等 [Su-ao thermal power generation project and plant site purchase, etc.]" *經濟部 [MOEA]*, Academia Historica Collection, no. 0310704000130, Academia Historica.

the Letzer industrial park in Su-ao as well. Together, a new bundle of economic benefits embedded in the proliferated carbon-intensive network was introduced to the Su-ao township, but this time it coincided with a substantial change in Taiwan's political climate.

3.4.2 Contested visions of the development of the Wuweigan Wetland

The silenced public sphere was gradually revived when the KMT's authoritarian regime was challenged after the US terminated governmental relations with Taiwan in 1979. Worrying the KMT might lose its majority in the Legislative Yuan, the government canceled the elections with no resumption date. This move provoked the "dangwai" activists, a label for pro-democracy activists who were not allowed to form a political party and referred to themselves as non-KMT party members. They began to issue "dangwai" magazines from 1979 to 1986 across the island to gain strength for mobilization.[161] The whistleblower of TPC's Su-ao project in 1986 was one of them, the *Kavalan Weekly*, which exerted significant influence in mobilizing the ensuing protests and stimulating public discussions on the energy issue.

Using the old name of Yilan County, Kavalan, as the title denotes its primary focus on local matters with a radical approach as its founders were important figures in the dangwai activities. *Kavalan Weekly* published its first issue in May 1986 by You Si-kun with Liu Shou-cheng as chief editor. By the end of that same year, the magazine's founders also actively participated in forming the major opposition political party, the Democratic Progressive Party. Since You and Liu both worked as the Councilor of the Taiwan Provincial Consultative Council during the 1980s and became Yilan County Magistrate in 1989 and 1997, respectively, the opinions on the *Kavalan Weekly* would be brought into the central government through Council meetings and actual decision-making practices.

The first article questioning TPC's Su-ao project was an interview with the Su-ao town mayor in October 1986, addressing the dust fall that Su-ao township had suffered and the town's resulting aversion to the thermal power plant. The dust was mainly from the aforementioned active cement plants in Su-ao township, and residents were worried that the TPC's plan would exacerbate the air pollution. Subsequently, a series of cover stories about TPC's public hearings and debates between TPC, experts, politicians, and residents were published in Kavalan Weekly and other dangwai magazines such as *Democratic Progressive Weekly*, *Freedom Era Weekly*, and *New Environment Monthly*.[162] It was the first time TPC had

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[161] Noting that dangwai activists was not a homogenous community but comprised of different factions with various approaches. See Shu-Lin Hsiao, "The Impact of the Tang-Wai Magazine influences the Tan-Wai Movement in Taiwan (1979-1986): Two Main Series of " The Eighties "serial magazines and "Formosa," "The Neo-Formosa" serial magazines." (Master National Central University, 2006).

[162] The last one is worth noted as it was issued by the New Environment Magazine Publisher that stood for antinuclear movement and public nuances since 1986. It later forged an important Not-Profit Organization, Homemakers United Foundation, represents a community-based and female-centered perspective that still yield great influence on the debates against nuclear power in Taiwan society today.

to explain to the public their long-range power development agenda to justify their Su-ao project.

Figure 11 of the Su-ao station's plant design in 1986 clearly shows that TPC had preserved spaces for eight coal-fired steam turbines rated at 150MW per unit. The delayed fourth nuclear power station increased the total installed capacity to cover the baseload demand. Issues that TPC was challenged with ranged from their load forecasting ability to the Su-ao project's fuel choice, coal quality, site selection, compensation schemes, and environmental protection measurements. In response, TPC delivered three versions of project design from 1986 to 1995. After publishing short stories about the project, You Si-kun interrogated the TPC manager as to the necessity of the Su-ao project in early 1987:

> "In a report conducted by Chung-hua Institution for Economic Research in 1985, it pointed out that over half of the TPC's facility became obsolete in the past five years, which means the facility utilization rate only reached 48 percent. The utilization rate in your current plan was only 51.7 percent in 1986. Why is TPC urged to push through the fourth nuclear power plant project if this number is correct? Now that the nuclear station is halted, you want to build the Su-ao thermal power plant?"[163]

In other words, You found TPC untrustworthy because they used an over-optimistic estimation of the annual growth rate of power demand to justify their development agenda. Several further cover stories discussing TPC's energy forecast and the question of whether building the Su-ao station would or would not cause frequent blackouts were published in *Kavalan Weekly* in 1989 and 1990. They were to counter the stories in mainstream newspapers about TPC, claiming a possible power shortage in the near future once the project was blocked. TPC found itself no longer the sole actor who could depict Taiwan's energy future.

You proceeded to claim that TPC's actual motivation behind the Su-ao plan was not to meet Yilan County's demand but to sacrifice the air quality and fishery resources of Su-ao in order to transmit extra power to other major cities. At the end of the meeting, You proposed several conditions for giving the green light to TPC. First, the Su-ao station should use low-Sulphur coal directly instead of adding expensive desulfurization equipment (approximately NT$ 40 billion per unit); or TPC should consider another fuel option, such as natural gas, to reduce the environmental impact as much as possible. On the other hand, TPC should figure out a compensation scheme for the potential hazard.

See Shih-jung Hsu, "New social movement, nonprofit organization, and community building in Taiwan: The case of Homemakers' Union and Foundation," *The Chinese Journal of Administration* 66 (1999): 1-20.

[163] "臺灣省議會第八屆第三次定期大會 [The third regular session of the eighth Taiwan Provincial Council]" *質詢/建設/總目 [Inquiry/Construction/General Content]*, Taiwan Provincial Council Collection, no. 0030803OA59640001682, Taiwan Historica.

In addition to the lamented pollutants, the disposal of pulverized coal ashes and thermal discharge would also directly impact the population of demersal fish (groundfish) and thus were of significant interest of the coastal fishery, especially fishers using trawling methods on the demersal zone. Therefore, TPC officials needed to deal with the debates inside the parliament and the economic conflicts with the local fishers’ community. As TPC began the marine survey on currents and waves at Su-ao harbour in 1987, around thirty fishermen filed complaints and disapproval to the Su-ao District Fishermen Association. Furthermore, because the TPC proposed site location overlaps with the expected fishing port designed for the offshore fishery, the Fishermen's Association could not agree to it either.

The vested political and economic interests brought a series of new actors into the debates in Yilan County, including politicians, residents, fishermen, and the Yilan Environmental Protection Union (YEPU). After a series of street protests, TPC held five public hearings in 1987, inviting stakeholders such as local representatives, the county council, the fishermen's association, and relevant scholars and experts to clarify their concerns but reached no consensus. Three years later, TPC came up with the second version by moving the controversial coal yard and outlets of thermal discharge off-shore to its 57 hectares of reclamation ground using the spoil disposal from dredging the south outline levee of the Su-ao port for TPC's coal terminal.[164] On the land, TPC would have to purchase 146 hectares of farmland in the Gangbian village for the plant site and 4.4 hectares of Su-ao port to build the coal conveyors. Moreover, it decreased the power units from eight to four, each rated at 750 MW. The total installed capacity increased from 1.2 GW in 1986 to 3 GW. As for compensation, TPC proposed to donate approximately NTD$ 1 billion every year to the local development fund of Yilan County and five-thousandths of actual electricity sales to the fund of Su-ao township in addition to paying property tax. Nevertheless, such a massive-scale plant led the residents to form the Gangbian Village Self-help Association in preparation for long-term fights in 1993.

Without many changes to the project details, after You Si-kun was elected the Magistrate of Yilan County, he went to urge the Governor of Taiwan Province to add the TPC's greenfield site, Ao-zai-jiao, in the Second Phase of Taiwan's Fishing Port Construction Plans (1988-1996), bringing the situation into deadlock.[165] In the meantime, TPC turned to the Letzer industrial park, where Formosa Plastics had already bought almost the whole park for building Taiwan's sixth naphtha cracking plant in 1987. The oil refining project was introduced to Su-ao township in the same year as TPC's project resumed in 1986. The president of Formosa Plastics Corp. promised to invest NTD$ 400 billion in Yilan County, and the County Council did not hesitate

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[164] TPC, *Su-ao Thermal Power Plant Environmental Impact Assessment Report: Ao-zai-jiao coal case*, Environmental Protection Administration (1991).

[165] Unknown, "台電蘇澳設廠凶多吉少, 游錫堃「捍拒」擬面見邱創煥 [Taipower's plans to open the Su-ao power plant are doomed, and You Si-kun "strong defends" by his planned meeting with Chiu Chuang-hwan]," *The Capital Morning Post* 1990.

to express their welcome in the first place. In the subsequent year, criticisms appeared in *Kavalan Weekly* about the then County Magistrate's decision to give consent with conditions. Anti-Su-ao and Anti-sixth-naphtha-cracking-plant movements became the two main themes of *Kavalan Weekly*.

Hoping to set foot in Yilan, Formosa Plastics Corp. purchased the land in the Letzer industrial park from the Industrial Development Bureau of MOEA for its refining plant. However, it failed to persuade the then Magistrate and his successor, You Si-kun. You stood firmly against more highly-polluted industries entering Yilan even when the then Prime Minister, Hau Pei-tsun, with a military background, adopted tough tactics to use the eminent domain to build the sixth naphtha cracking plant the exchange for the Freeway No. 5 interconnecting Su-ao and Taipei City.[166] This action provoked the "Democratic Alliance of Magistrates," which comprises six DPP members, including You, and one not affiliated with any party, to draw a joint statement to support You's position. He then directed the Water Resource Bureau not to issue permission for industrial water use of the plant and forced Formosa Plastics Corp. to drop their proposal in 1991.

The departure of Formosa Plastics Corp. gave TPC a glimpse of hope of going through without land acquisition troubles by moving the plant site to the Letzer industrial park. Moreover, as mentioned earlier, Yilan County's annual financial budget was relatively tight; thus, infrastructural improvements and the feedback fund from the national project were enormously influential. As TPC proposed to relocate to the industrial park, the economic incentive had turned the representatives of Su-ao township into a conditional agreement. According to the proposed 13 conditions, the representatives demanded that TPC make sure the construction of the Su-ao station would be set in motion along with the Ao-zai-jiao fishing port. The feedback scheme was expanded to include funding a junior college, a hospital, a concessional electricity rate, and a rise of Su-ao township's share of feedback fund to over 50 percent.[167] While the representatives of Su-ao township focused more on the supported facilities and infrastructure of the Su-ao project, the You-led Yilan County administration formulated a much more specific framework: only if TPC agreed to degrade the total installed capacity to 800MW, shift its fuel to natural gas, use the closed-cycle cooling system, sign an environmental MOU with the County government, and provide the feedback fund.[168]

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[166] Min-xian Wu, "游錫堃: 反六輕立場不變, 是否仍反蘇澳火力發電廠, 要看專家評估 [You Si-kun: The anti-sixth-naphtha-craking plant stance remains unchanged. Whether we are still anti-Su-ao thermal power plant depends on expert assessment.]," *United Evening News* 1991.

[167] Cheng-zhong Chen, "建蘇澳電廠 13 條件 台電無法照單全收, 由「誓死反對」到鎮代會「有條件協助」成果得來不易 [13 conditions for building Su-ao power plant. Taipower cannot accept all the conditions. From "deathly opposition" to "conditional assistance" from the town representative meeting, such results are not easy to come by.]," *United Daily News* 1991.

[168] Qi-tao Zhao and Min-xian Wu, "宜縣提出五條件未獲中央回應, 反對興建蘇澳火力發電廠, 游錫堃: 暫關閉縣府大門, 揚言將以拒發水權證明等手段, 強烈抵制 [Yilan County put forward five conditions but received no response from the central government and opposed the construction of Su-

In response, TPC's third version contained only two fuel oil-fired steam turbines rated at 750MW per unit. By moving to the Letzer industrial park, TPC had to reduce the size from the original 203 hectares to 88 hectares, abandoning its coal yard, terminal, and conveyor. Instead, the project design shifted back to fire fuel oil which also helped to cut down 45 percent of the construction cost. The reason behind such a choice instead of natural gas was that CPC only began importing liquefied natural gas (LNG) in 1991. The fuel network for integrating LNG terminals was not ready to support TPC's Su-ao station's huge demand. As Figure 12 shows, the two units would consume 2.04 million tonnes of fuel oil annually based on TPC's estimation. Therefore, they planned to procure low-sulfate fuel oil (less than 1 percent, lower than coal) and diesel oil (lower than 0.5 percent) from CPC and build oil tanks for storage at the site and Su-ao port, respectively. Fuel oil would be pumped from the Su-ao port through an underground pipeline to the site, and the generated electricity would be transmitted to the grid through the extra-high-voltage transmission lines.

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ao thermal power plant. You Si-kun: Temporarily closed the main entrance of the county government and threatened to strongly resist by refusing to issue water rights certificates and other means.]," *United Daily News* 1992.

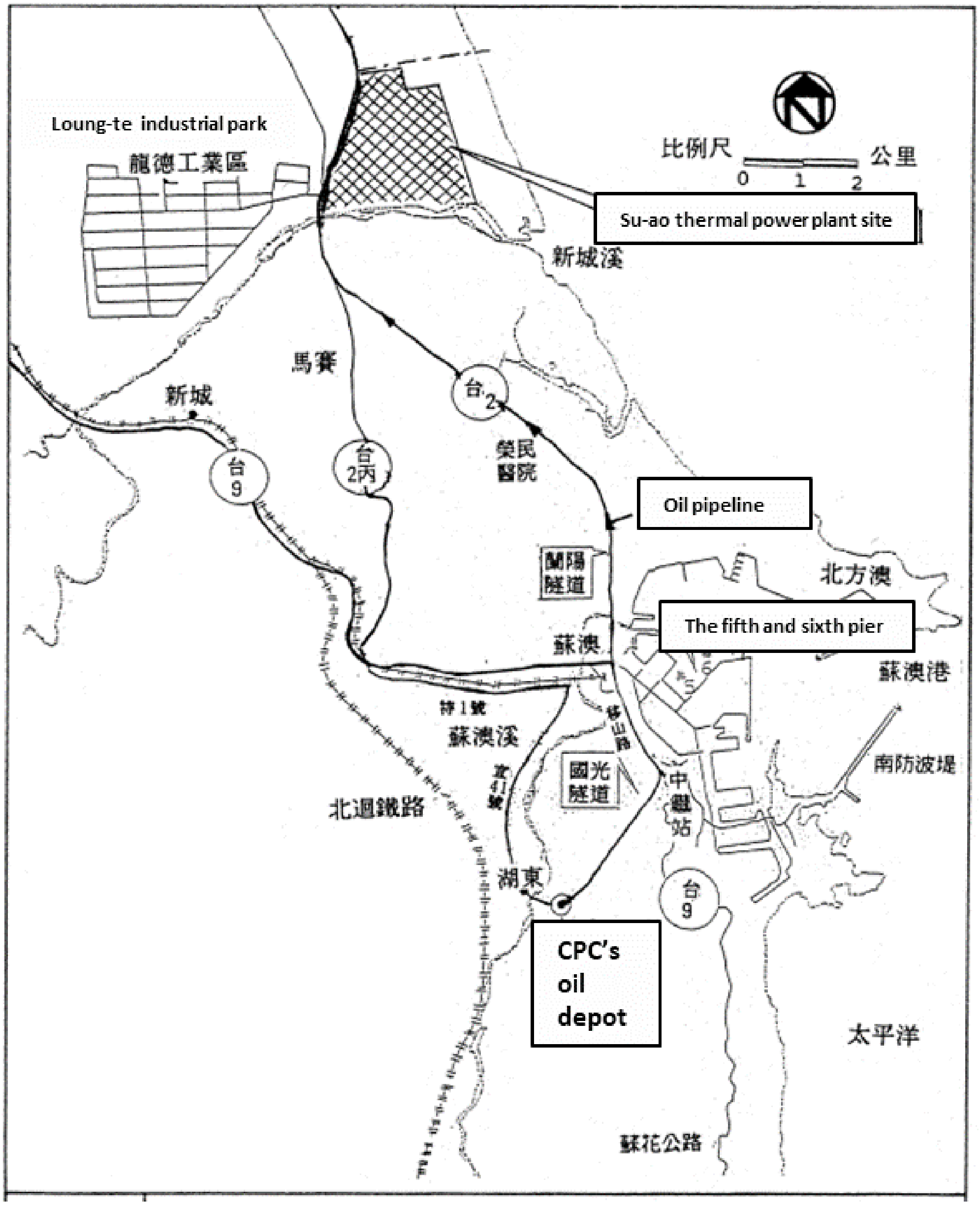

Figure 12 A diagram of the fuel oil transportation system of Su-ao station in TPC's Environmental Impact Assessment Report of 1994.

Source: Excerpted from the TPC's Environmental Impact Assessment Report of Su-ao Thermal Power Plant in 1994, pages 4-16.

Despite the compensation scheme added in promising Ao-zai-jiao fishing port's completion along with the power station, the revised project did not fit well into either Su-ao township's or the Yilan County's frameworks. You's administration planned to adopt the same strategy toward Formosa Plastics by withholding the permission to use industrial water to continue the negotiation. Since neither the County government, the fishing community, nor the self-help association seemed strong enough to ensure that TPC would not restore the project to Ao-zai-jiao and Gangbian village, people sought help from the wildlife preservation movement, which made Wuweigan the new battle ground (Figure 13).

Figure 13 The landscape of Wuweigan wetland in 2023.

Source: Photographed by the author.

Wuweigan is located at the center of Gangbian village. It used to be a small fishing port, but after the river mouth was blocked due to the floods caused by the 1968 Nading Typhoon, Wuweigan became an in-land floodplain and an essential stop for migratory avians. Early in 1988, a report on Asian Wetland Outlook conducted by an international waterbirds research center and the International Union for Conservation of Nature and Natural Resources listed Wuweigan as one of the important wetlands in Taiwan. In 1993, the Agricultural Department of Yilan County declared the establishment of the Wuweigan Bird Sanctuary under the Protection of Wild Animals law which is Taiwan's first wetland birds' preservation zone. The wetland birds became the last straw for TPC to give up the Su-ao project entirely after the third version did not gain public consent.

To sum up, the anti-Su-ao movement shows how in the changing political climate in the 1980s, when the DPP gained strength from its alliances with grassroots organizations, TPC found itself faced with a high threshold for expanding its system to deal with the two global energy crises and economic recessions. This is not a new insight. Scholars have already noticed that political coalitions were built around Taiwan's major public nuisances through the 1980s.[169] To be sure, these were not individual events, as the above story of the anti-Su-ao

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[169] Ming-sho Ho, "Understanding the trajectory of social movements in Taiwan (1980-2010)," *Journal of Current Chinese Affairs* 39, no. 3 (2010): 3-22; Ho, "Environmental Movement in Democratizing Taiwan (1980–2004): A Political Opportunity Structure Perspective."; Ming-sho Ho, "The early stages of Taiwanese environmentalism: Intellectuals, tangwai, and grassroots organizers (1980-1986)," *Taiwanese Journal of Sociology* 2 (2001): 97-162; Ming-sho Ho, "Political democratization and institutionalization of environmental movement in Taiwan (1933-1999)," *Taiwan: A Radical Quarterly in Social Studies* 50

movement has shown; they were, in fact, a collective response to the carbon-intensive network. Especially the successful social movement framework involving non-human actors (in this case, wetland birds) in energy debates broadened the scope of energy discussion in Taiwan and became one of the primary means to protest against other carbon-intensive networks' projects afterward – as we will see in Chapter 4 with dolphins and in Chapter 5 with the Datang algal reef.

3.5 Concluding remarks

The 1970s-80s were a critical period in the development of Taiwan's current energy policy and power system. The existing historiography of the 1970s focuses on the rising prices of foreign oil and Taiwan's worsening diplomatic situation, both of which directed Taiwan's energy policy toward diversification; and subsequently, TPC and the government used their framing of the perceived crises to justify installing nuclear power plants to substitute imported fossil fuels.[170] However, the statistics on the electricity mix suggest that TPC had not given up using oil in the 1970s. While most scholars focus on the idea of energy security in understanding the national responses toward the two oil crises, this chapter offers a different lens of observation from the aspect of TPC's agencies in terms of their managing strategies of fuels and Taiwan's flexibility as a global island. Furthermore, it echoes the literature that views energy history as a reflection of national history and seeks to give new insights regarding the global energy crisis from the perspective of a marginalized island country. Under certain political and geographical constraints, TPC's agency to deal with various energy crises tells a different story than is reflected in simplistic narratives of a bipolar Cold War world.[171]

The first section examined Taiwan's energy decision in a broader context of the East Asian region. I then proceeded to explain that TPC was not new to the idea of energy diversification with its experiences in dealing with the problems of domestic coal. Since the late 1960s, TPC has already integrated its business into fuel mining, shipping, and storing. By utilizing the fuel interchangeability of steam turbines and its engineers' network through foreign technical assistance programs and domestic co-investment, it could extend the power system and fuel network based on hydrocarbon fuels. The second oil crisis had different impacts on the TPC system as the electricity growth rate descended, and TPC was forced to face the consequences by over-focusing on fuel flexibility rather than system flexibility with its overstored coal yards and oil tanks in the 1980s.

(2003): 217-50; Ming-Sho Ho, "Taiwan’s anti-nuclear movement: The making of a militant citizen movement," *Journal of Contemporary Asia* 48, no. 3 (2018): 445-64.

[170] See also Hsu, "Advocacy coalitions and policy change on nuclear power utilization in Taiwan."

[171] Erik van der Vleuten, "In search of the networked nation: Transforming technology, society and nature in the Netherlands during the twentieth century," *European Review of History: Revue européenne d'histoire* 10, no. 1 (2003): 59-78. Akira Iriye, "Historicizing the Cold War," in *The Oxford Handbook of the Cold War* (2013), 15-49. Hajimu Masuda, *Cold War Crucible: the Korean Conflict and the Postwar World* (Harvard University Press, 2015), 388.

Meanwhile, the construction of Taiwan's nuclear power plants since the late 1970s is often rendered as the solution to the fluctuating oil prices. However, as the historical review in the second section showed, nuclear power units fit well into TPC's expansion logic and helped to sustain its thermal power-based system instead. Finally, with the system's increasing complexity and scale, its consequences also became visible to the public in the form of accompanying pollution. The remainder of the chapter discussed how the TPC system responded to the escalating pressure during the 1980s. By specifically looking into the Anti-Su-ao thermal power plant movement from 1986 to 1995, I explain a significant transformation of Taiwan's energy politics with a new set of actors engaging in the decision-making process.

Looking into TPC's energy decisions during the 1970s to 1980s, we can see that the arguments surrounding coal, oil, nuclear fuels, and LNG should be understood in both technical terms and in a social context. As TPC's failing Su-ao project had shown, fuel oil even became the optimal choice for the TPC system to overcome the political obstacles at one point. It suggests that what made energy carriers ideal, either coal, oil, nuclear, or renewables, depends on whether the energy technology could fit into the changing political, social, and environmental landscapes. To take this point further, the next chapter uses Taiwan's offshore wind energy development as a case in point to discuss how this new energy technology adapted itself into the mature TPC system and provoked changes within the local society in the post-Fukushima era.

Chapter 4: Renewable Transition in the Making

The previous chapter explained how the government granted and increased TPC's agency to deal with multiple crises from the late 1960s through the 1980s. Its carbon-intensive network – the fossil fuel-based power supply and consumption structure interlinked by subnetworks of the fuel system — extended across regions and innovated to maintain the system's growth (while also arousing opposition). For example, the Taiwanese government began to promote the co-generation system in 1988. Allowing factories to install co-generation units that combine industrial heat and power generation for self-use or sale in bulk to TPC was one of the measures to ease the pressure on TPC's power supply. By integrating such small and decentralized generators into their system, TPC established and strengthened ties with industrial users. In other words, as the system builder, TPC struggled to maintain systemic expansion, particularly in light of their delayed plans for a fourth nuclear station. Therefore, TPC had to allow additional elements not under its control. In addition to the decentralized co-generation unit, renewable energy resources, especially solar and wind, were also welcomed as an ideal means for expanding the TPC system in the face of multiple challenges in the 2000s.

Previous studies have identified Taiwan's high dependency on imported energy (which might hinder Taiwan's economy and national security) and the urge for transnational cooperation in tackling climate change through decarbonization in the late 1990s as the driving factors in turning Taiwan's energy policy toward a renewables transition.[172] Indeed, national discourse delivers the same message, for example, in the language of policy reviews. Only the role of nuclear power has varied in the different ruling parties' blueprints as either the primary contributor to Taiwan's decarbonization or the target of phasing out. As chapter 3 showed, the attitudes toward the construction of TPC's fourth nuclear power plant became a crucial event manifesting Taiwan's political polarization, for its halt was a result of Taiwan's concurrent democratization and the rise of environmental movements in the late 1980s.

However, renewable energy was not always rendered as the solution to the above problems. In retrospect, Figure 14 shows the composition of installed capacity by different energy sources within TPC's power structure from 1950 to 2021. Renewables' share slowly grew from 5.7 percent (218.38 MW) in 2008 to 21.6 percent (1.1 GW) in 2021. Looking closer at the contribution of energy types, the significant growth of solar photovoltaic installations was the main reason for renewables' increased share (Figure 15), even though wind power systems secured R&D investments and policy promotion first. Before the 2000s, TPC put a 3 MW geothermal plant and small-scale wind power projects into operation in the 1980s. Both

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[172] For a few examples, see Kuo, *The Impacts of Energy Trends and Policies on Taiwan's Power Generation Systems*; Trappey et al., "An evaluation model for low carbon island policy: The case of Taiwan's green transportation policy."; Tsai, "Current status and development policies on renewable energy technology research in Taiwan."

were built for research purposes and shut down afterward. These early developments – and their abandonment – show that it is essential to historicize renewables over the long term to understand Taiwan's shifting course toward a renewable transition.[173]

By looking closely into the different social contexts of Taiwan's renewable energy development, this chapter asks, what purposes did renewable energy resources serve within the TPC system's evolution? What boosted Taiwan's renewable development in the 2000s? And finally, what does enlarging the capacity of renewable electricity entail for the local society and the existing carbon-intensive network? Answering these questions will help to explain the path dependence of the carbon-intensive network that shaped Taiwan's current renewable development. Taiwan's wind power development will be discussed in detail to illustrate the sociotechnical changes that were brought to the existing network.

Returning to the 1960s, the first section of the chapter describes TPC's early attempts at harnessing wind power and gives an overview of the context for Taiwan's renewable energy development. It does so to highlight the different purposes that renewables served throughout the TPC system’s evolution. As the story unfolds, it explains why it was not the 1970s energy crises that made renewables an ideal option but the social upheavals in the 1980s that triggered Taiwan's first market deregulation and paved the way for the pro-renewable power brokers to participate in Taiwan's monopolized electricity market and TPC system.[174] The second section deals with the origin of the seemingly rivalrous relationship between nuclear and renewables. As Taiwan's anti-nuclear movements coincided with the serious challenges of the nuclear industry globally in the 1990s, this section traces how harnessing renewable resources was justified amid nuclear debates in Taiwan's parliament and how renewables gained cross-party political and financial support in the 2000s. In turn, Taiwan's renewable energy development became more entangled with the controversial nuclear units. The subsequent 2011 Fukushima Incident further escalated the tension to a new level and led the KMT-led government to commit to promote wind power development through more policy instruments. The third section discusses the systemic impacts of the penetration of wind power. From the early, relatively small-scale onshore wind projects to today’s centralized offshore wind farms, this section closely examines the characteristics of the different wind conversion technologies and follows the controversies that they aroused within local societies and the TPC system. In so doing, it highlights how social and technical conflicts become inextricably intertwined and yield influence on the carbon-intensive network.

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[173] Hasenöhrl and Kupper, "Historicizing renewables: issues and challenges."; Hasenöhrl and Meyer, "The energy challenge in historical perspective."

[174] Jeremiah D Lambert, *The Power Brokers: The Struggle to Shape and Control the Electric Power Industry* (Mit Press, 2015), 400.

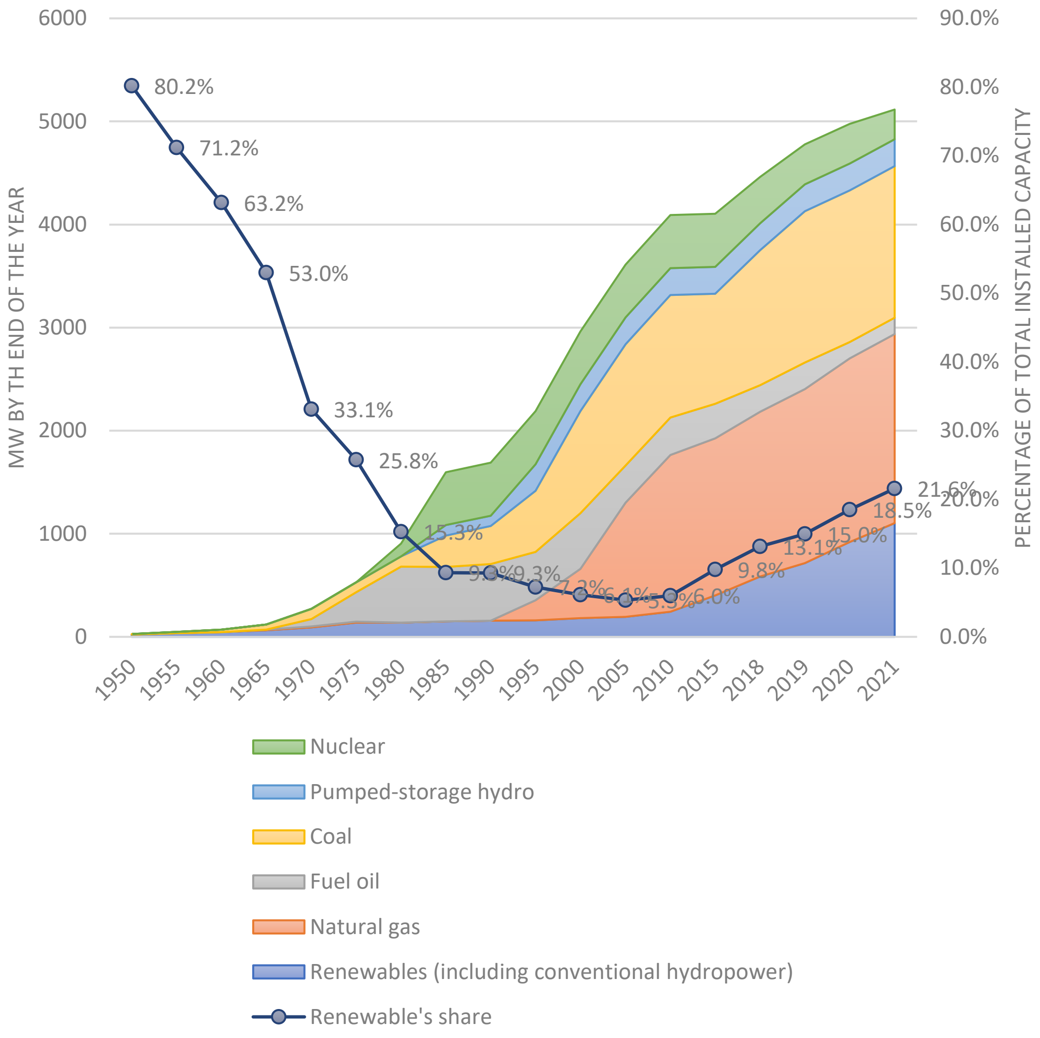

Figure 14 Taiwan's cumulated installed capacity by energy sources, 1950 to 2021.
Source: Data extracted from the Taipower Company's website.

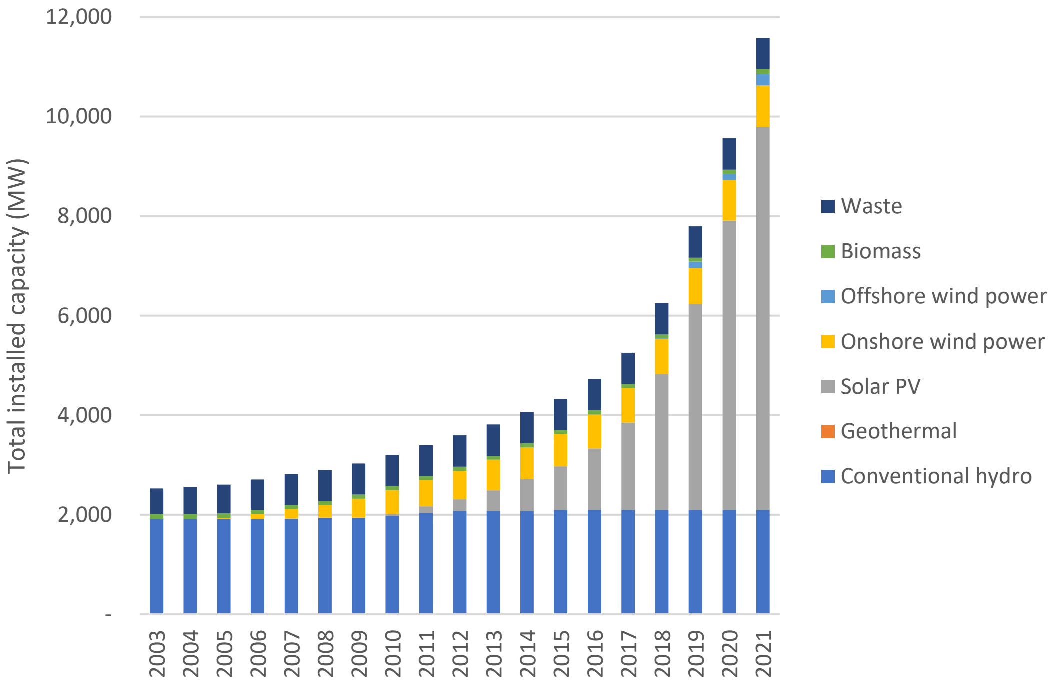

Figure 15 The installed capacity of renewable energy from 2003 to 2021.
Source: Data extracted from the Taiwan Power Company's website.

4.1 Back to a failed experiment on an offshore island

Taiwan’s relatively low share of renewable energy in TPC’s total installed capacity is not because of a lack of effort. This section explores the context of how renewables (including solar and wind) were introduced into the TPC system and their changing purposes over time.

TPC's interest in unconventional energy technologies can be traced to the early 1960s. When the UN held its 1961 conference on *New Sources of Energy: Solar Energy, Wind Power, and Geothermal Energy*, TPC sent Chou Chun-Chuan, the director of TPC's electrical and mechanical maintenance factory, accompanied by two professors and a solar heat researcher based at Wisconsin University, as Taiwan's representatives. According to Chou's report, although the utilization of solar power took up most of the discussion panels, transitions from solar heat to electricity generation were still under research. From his perspective, solar water heaters were the most promising and feasible option for Taiwan; in the end, it took two decades for solar heaters to hit the market, and only then thanks to a subsidy provided by the Taiwanese Government in 1986. On the other hand, the early Danish wind power development already caught Chou's eye in 1961.

Johannes Juul, the Danish pioneer in developing the world's first AC wind turbine in the 1950s, presented papers at the 1961 UN conference on the interconnection of wind power with Denmark's power system and the economy and operation data of the Bogø and Gedser plants.[175] Chou was impressed by Juul's presentation about the then-largest three-bladed upwind turbine at Gedser, rated at 200 KW.[176] After the conference, he went on a field trip to visit the sites, hoping to bring back the experience to Taiwan's Penghu County (Pescadores Islands). The main isle of Penghu is located 45 km away from Taiwan's western coast relying mostly on diesel generators with relatively expensive fuel costs at the time. The generation cost of Gedser was USD$ 0.000105 per KWH compared to Penghu's thermal units' USD$ 0.0205 in 1959.[177] Aside from the economic incentive of significant operational cost decrease, another attraction was that wind power would allow the islands to reduce dependence on fuel deliveries – an essential factor considering the unsettled Taiwan Straits crises of the 1950s.[178] US interventions helped (temporarily) resolve those disputes, but the sense of ongoing warfare encouraged the TPC engineers to prepare for wartime interruptions when conducting system planning. Furthermore, Chou concluded in the report that harnessing wind power presented a great opportunity to level up Taiwan's electric equipment industry as well.[179]

The reason behind his focus on the electric parts possibly comes from Chou's personal experience. Chou was a Taiwanese electrical engineer who joined the TPC during Japanese rule. His working experiences with turbines at the Sun Moon Lake hydropower plant during the 1930s and internship experience with Westinghouse in TPC's early post-war rebuilding period afforded opportunities to learn about the operation of transformers, generators, and other electrical parts. That knowledge made him the ideal person in directing TPC's first wind

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[175] Juul's papers were carried back to TPC and translated in Mandarin on the *Monthly Journal of Taipower* for circulation, including Juul Johannes, "Design of wind power plants in Denmark" (United Nations Conference of New Sources of Energy: Solar Energy, Wind Power, and Geothermal Energy, Rome, United Nations Publications, New York, August 21-31 1961); Juul Johannes, "Recent developments and potential improvements in wind power utilization for use in connection with electrical networks in Denmark" (United Nations Conference of New Sources of Energy: Solar Energy, Wind Power, and Geothermal Energy, Rome, United Nations Publications, New York, August 21-31 1961); Juul Johannes, "Economy and operation of wind power plants" (United Nations Conference of New Sources of Energy: Solar Energy, Wind Power, and Geothermal Energy, Rome, United Nations Publication, New York, August 21-31 1961).

[176] An upwind turbine design has its rotor directly face the opposite direction of wind flow, and benefits from the prevention of tower shadow effects, which might reduce the power generating capacity for a downwind design. The horizontal-axis wind turbines with a three-blade rotor upwind of the tower become the predominant design in the wind power generating industry. For further details on the changing and competing technical features of wind turbines, see Paul Gipe and Erik Möllerström, "An overview of the history of wind turbine development: Part I—The early wind turbines until the 1960s," *Wind Engineering* 46, no. 6 (2022): 1973-2004.

[177] Chun-chuan Chou, "Epilogue of attending the UN New Sources of Energy Conference," *Monthly Journal of Taipower's Engineering*, no. 160 (1961): Inside front cover.

[178] The PRC launched two bombardments on Jinmen, Mazu and Dachen Islands, the offshore islands of Taiwan, in 1954 and 1958. In response, the Nationalist government acted on the opportunity and sent troops to invade the coastal cities on the mainland China when the first crisis broke out. Douglas Porch, "The Taiwan Strait Crisis of 1996: Strategic implications for the United States Navy," *Naval War College Review* 52, no. 3 (1999): 15-48, http://www.jstor.org.mu.idm.oclc.org/stable/44643008; Melvin Gurtov, "The Taiwan Strait crisis revisited: Politics and foreign policy in Chinese motives," *Modern China* 2, no. 1 (1976): 49-103, http://www.jstor.org.mu.idm.oclc.org/stable/188813.

[179] Y. S. On, "丹麥的風力發電（下）," [Wind power in Denmark (a continued article).] *Monthly Journal of Taipower's Engineering*, no. 160 (1961): 13-21.

power experiment, in that converting the mechanical energy of a rotor from wind to electrical energy was not so different from his prior work converting mechanical energy from water to electrical energy.[180] Learning from the Danish Gedser design, the Chou-led TPC maintenance factory manufactured and assembled Taiwan's first 50KW wind turbine, and successfully installed the turbine in Houliou Village on Baisha Isle in 1965 (Figure 16). From the blade design to the nacelle structure, which contained vital parts such as the gearbox and generator, TPC's turbine was basically a scaled-down version of Gedser's.

However, Chou's hopes of using wind power as the baseload power with supplemental support from the existing diesel units and promoting the birth of Taiwan's wind industry faded along with the experimental turbine's dismantling in 1972. According to a review article written by Chou's staff, the reasons for the research termination included an issue with rusting of the nacelle and the difficulty of constant maintenance due to the factory's distance from Taipei.[181] Nevertheless, after 7-years of trial and error, the TPC engineers learned ways to improve the design, such as substituting different materials for the originally easily broken turbine blade. They also realized that the turbine needed to scale up to at least 150KW to 200KW (similar to the Gedser design) to cover the generation cost.[182] However, the estimated expense for research and manufacture would be NTD$ 3 million (approximately equivalent to USD$ 693,101 today), which TPC's maintenance factory could not possibly afford. Especially considering TPC's maintenance factory was not an actual electrical parts manufacturer, the spillover effect of such innovation was somewhat limited, and the market barrier was high. In short, technology transfer from the Danish wind experiences was much less of a problem than the lack of a supportive network.

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[180] Qiong-rou Lin, "承恩典、展長才，介於兩個時代的台電耆老 [Inheriting grace and developing talents, Taipower seniors in-between two eras]," *Yuan Magazine*, 1998, 38-43.

[181] Zeng-ying Lai, "台電修理廠試製 50KW 風力機簡報," [A manufacture briefing of the 50KW wind turbine by TPC's maintenance factory.] *Monthly Journal of Taipower's Engineering*, no. 304 (1973): 1-5.

[182] It is worthy to note that although the installation cost and performance might break even at the rate of 150KW or 200KW, the Gedser design in Denmark was still rendered lack of economic feasibility compared to the steam power generators later in the Danish Wind Power Committee’s report of 1962. Instead, the Danish wind power committee found wind power valuable as auxiliary power supply in case of the shortage of imported fuels. See *Report of the Wind Power Committee*, Danske Elvaerkers Forening (Copenhagen, 1962).

Figure 16 TPC's first experimental wind turbine rated at 50KW was commenced in 1965.
Source: Excerpted from TPC, "Taipower 1965," in *Valery S. de Beausset and U.S. Aid to Taiwan*
(ntul_db03_03_001_02: National Taiwan University Library, 1966).

Looking closely, the Houliou Village project's fortunes were very different from those of the Gedser project. The Danish experimental project at Gedser was launched in 1955 by a Wind Power Committee under the supervision of the Association of Danish Electricity Works (Danske Elvae kers Forening, DEF). The committee received funding from the Danish Government up to Danish Crown 525,000 (about $80,000 today) for construction, measuring equipment, and management of the project. Considering that recording the varied wind speed and directions on a long-term basis is crucial in terms of wind turbine operation, not only was an anemometer placed below the hub to observe the wind speed, another three wind-measuring cylinders at heights of 25 and 50 meters were built in collaboration with the wind laboratory alongside the Gedser project.

In comparison, although a meteorological mast at Penghu Weather Station already existed in 1898, its location on Magong Isle was far from the project site. The absence of an industrial network, financial aid from the government, and observation networks for recording long-term meteorological data all undermined Chou's ambitious wind project. TPC's second attempt to try out wind turbines had to wait a decade later until 1987. Another short-lived demonstration site with two 100KW wind turbines using direct-drive motor design – closely modelled on Chou's original expectation – was established on Qimei Isle. This timing has to do with the government's R&D support through the Industrial Technology Research Institute (ITRI) in the early 1980s. ITRI's role in facilitating Taiwan's renewable energy industry will be discussed in the following section.

Generally speaking, in the 1960s, TPC considered wind power units as an exceptional remedy for Penghu's isolated power network, rather than an energy technology that could feasibly be integrated into the TPC system. As a result, Penghu Islands have become Taiwan's site of experimentation with new emerging technologies, including green ones, as will be detailed in the next section. As the second and third chapters have shown, TPC embraced imported fuel oil and the promise of nuclear technology in the following decades. Therefore, it had few resources for advanced research in wind power or other nascent energy technologies on the main Formosa Island. This is not to deny TPC's early research efforts in searching for additional power units to respond to the uncertainty of imported fuel oil. With the revised national energy policy of 1979, the government requested TPC to allocate 0.01 percent of its revenue to R&D, half of which would be given out as energy research grants.[183] Subsequently, TPC proceeded with its prioritized research projects during the 1970s: imported coal, nuclear power, wind power (for offshore islands and Tornado type wind energy system for the Formosa Island), tidal and ocean thermal energy conversion on the east coast. Nevertheless, it was not until the 2000s that TPC considered systematically integrating renewable power units into its grid.

The escalating pressure since the late 1980s from citizens' concerns about pollution caused by both its fuel network and power stations (either thermal or nuclear) opened the long-monopolized market in the 1990s. Although the original intention behind the first phase of market liberalization was not for the growth of individual power producers (IPPs) but to maintain the momentum of TPC's expansion, such regulatory changes also gave economic incentives for decentralized renewable units. The next section explores the formation of the pro-renewables coalition to explain how renewable energy technologies drew attention from various interests and became the solution for all.

4.1.1 Beginning with ITRI: The emerging network for Taiwan’s renewable energy development

> In the recent past, we were thinking about bigger units and bigger networks. Economy was to be achieved through scaling up. But now we are confronted with a rather different picture in renewable energy resources. None of the devices or facilities we can build in this connection will be very large. These energy resources become highly valuable to our society only when they are combined and conditioned. This would call for renewed efforts in planning and in managerial techniques…When we are working on renewable energy resources it is perhaps quite necessary that we begin to think small more than

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[183] "臺灣地區能源政策執行情形 [Implementation of Taiwan's energy policy]", no.,

> thinking big. *Former President C. K. Yen's Speech at the ROC-USA Workshop on Renewable Energy, May 10, 1982.*

Yen's opening speech at the 1982 ROC-USA Workshop on Renewable Energy hinted at how renewable energy sources might play a role in the TPC system. He was partly correct in thinking that renewables would remain small compared to the installed size of thermal units (already rated at 550MW) and nuclear units (636Mwe) at the time, but to connect renewable units to TPC's grid their capacity would still need to exceed those of the Penghu experimental turbines. Oddly, wind power was left out of the workshop, perhaps because operational costs had proven uncompetitive compared to the diesel units on the Penghu Islands. Another possible reason comes from the background of Yen's speech writer, Yeh Hsuan, the 1982 workshop convenor and the co-founder and first director of ITRI’s just-established Energy Research Laboratory.

Receiving his doctoral degree from the Massachusetts Institute of Technology, Yeh specialized in fluid engineering and worked at Johns Hopkins University in the 1950s, at a time when the main application of solar panels were mainly applied to aerospace power systems. Before Yeh's return to Taiwan, he worked at the Executive Committee of the Intersociety Energy Conversion Engineering Conference between 1970 and 1982. The conferences gathered experts on the Stirling engine, electric power systems, photovoltaic systems, and energy storage. Yeh’s prior working experience in organizing the conferences between 1970 and 1982, in which panels were similar to those in the later held ROC-USA workshop of 1982, also explain why the ROC-USA workshop of 1982 had targeted new energy technologies such as anaerobic digestion, solar salt ponds, solar cooling, photovoltaics, mini-hydro devices, Stirling engines, and geothermal energy, instead of wind power.[184]

Once again, the network of transnational experts had an important place in Taiwan’s science policy and research program. Such a Sino-US cooperation on energy technologies took place not only because the two countries shared the same energy concerns during the second oil crisis but also for diplomatic reasons especially after the establishment of the Taiwan Relations Act in 1979. In terms of energy reality, as the US faced domestic pressure on the private utilities' monopoly status, the themes of the ROC-USA series workshop – ranging from industrial energy conservation to renewable energy – show the shared interests in facing the energy issues entangled with the debates over government intervention, over-consumption, environmental concerns, and technical improvement (to bring large-scale units online to further drive down costs) in the 1970s and 1980s. In the US system, especially after the Public Utility Regulatory Policies Act was passed in 1978 and removed the barriers for IPPs to sell power to the regulated utilities, the lobbyists' and state regulatory body's roles in bringing

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[184] "中美再生能源研討會 [ROC-USA Workshop on Renewable Energy]" *錢思亮 [Qian Si-liang]*, no. 303-01-01-05-047, Archives, Institute of Modern History.

liberalization forward within a restructured electric utility system were significant.[185] Approximately in the same period, Taiwan's network for stimulating such structural reform was about to emerge with ITRI's founding in the 1980s.

Established in 1973, ITRI was a result of an institutional integration between three industrial research institutes, including the Metal Industrial Research Institute, the Mining Research and Service Organization, and the Union Industrial Research Institute. As mentioned in Chapter 2, the birth of UIRI signals Taiwan's early effort in developing applied science in the 1950s. When Sun Yun-suan became the Minister of Economic Affairs, he hoped Taiwan could have a research institute to boost high-tech industry similar to the Korea Advanced Institute of Science and Technology (KAIST) in South Korea. Thus he initiated the merger of the three major industrial research institutes to form a single institute with a more cutting-edge focus and greater mandate. Ergo, ITRI came into being as the government's significant R&D contribution to Taiwan's integrated-circuit industry, which spun off Taiwan's leading semiconductor companies, United Microelectronics Corporation and Taiwan Semiconductor Manufacturing Company (TSMC), in 1980 and 1987, respectively. The development of semiconductor materials for microelectronics stimulated the popularity of photovoltaic solar cells and signalled the shifting research focus from solar heat to power conversion. Aside from the technical feasibility of solar panel manufacturing, when Yeh started the energy lab in 1980, it showed the growing attention toward solar power systems.[186] Furthermore, ITRI became the hub for nurturing innovative energy technologies and renewable industries in Taiwan. For example, through technology transfer from ITRI's lab, Yeh established Taiwan's first photovoltaic panel manufacturing company, Sinonar, at the Hsinchu Science Park in 1988. ITRI also nurtured many talents from its energy lab. Hong Chum-sam was one of them as another important figure in Taiwan's solar industry, who also spoke in the photovoltaic session of the 1982 workshop. Hong's career progressed from a researcher on solar cells to a member of Yeh's group at Sinonar and later co-founder of Taiwan's largest solar cell producer, Neo Solar Power company, in 2005.

To advance the research and application of solar technologies in Taiwan, these first-generation solar researchers formed the Solar Energy Society of Taiwan (now Solar and New Energy Society of Taiwan) in 1980, which mainly gathered researchers based at universities or ITRI but later expanded to involve private solar companies and personnel from the Energy

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[185] Hirsh Richard, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System* (MIT Press, 1999), 418.

[186] The goals of ITRI's solar power related programs were not only studying and experimenting potential products in their labs but also to establish a series of testing standard to help the domestic manufacturers maintain competitive with fine product quality. For instance, during 1983 to 1988, ITRI began to develop and fabricate low-cost a-Si:H Solar cells in its lab; meanwhile, ITRI also devoted research efforts in building an 1KW Photovoltaic Testing System for the PV modules manufactured in Taiwan. See ITRI, *The Research on Photovoltaic Testing System*, Energy and Mining Research Institute, ITRI (Hsinchu, 1984). ITRI, *The Study and Fabrication of a-SI:H Solar Cells*, Energy and Mining Research Institute, ITRI (Hsinchu, 1984).

Bureau. In other words, outside the TPC system, the research-industry-government network and value chain for Taiwan's solar power development has been gradually taking shape since the 1980s. Furthermore, these talents trained in ITRI's energy lab not only led the growth of the solar businesses but also became the renewable advocates who pursued governmental subsidies and a more renewable-friendly political environment. Here, it seems clear that the failure to stimulate such associations had caused Taiwan's relatively delayed wind power development, and the reasons behind such failure were part of technical limitations and part of the developmental path that ITRI’s energy lab took on.

TPC's early attempts at Penghu Islands had exhibited the lack of economic incentives for building a turbine under 100KW. Yet, ITRI's energy lab still embarked on research into 4 KW wind turbines in 1980. The seemingly "back to zero" approach exemplifies a different developmental purpose conceived no longer under the circumstances of possible warfare but under the stress of energy security after the 1970s oil crises. To be more specific, ITRI's energy lab did not attempt to develop large-scale wind energy technologies because ITRI had no authority to direct TPC's planning scheme regarding alternative energy. There was no exchange record of information between TPC and ITRI about the early design details and report of the 1965 self-made turbine either. At the same time, TPC launched another experimental project on Qimei Isle with two imported direct-drive turbines suggesting a parallel development.

The lab's goal was clear. In the initial phase of the lab's establishment, Chin-Sung Chiu and his research fellow, released a report on wind energy development in the U.S. and Taiwan, stating that the purpose of alternative energy research should not be substituting for conventional energy technologies. Instead, wind turbines should be introduced to Taiwan's power system as auxiliary units in case of another energy shortage crisis and to help develop new domestic energy industries.[187] In other words, they intended to create an industrial chain of domestic manufacturers to produce small wind systems that could be applied in remote regions, not confined to offshore islands, for irrigation and electricity generation.

Under such a scheme, there were two major tasks at hand. One was charting wind potential by conducting surveys in different regions, as the lack of general and long-range meteorological data remains a problem in deploying and commercializing wind turbines in Taiwan. Second, setting up the wind industry. Since the early research programs on wind power were often short-lived due to budget limits and a lack of integration, the lab played the leading role in initiating the industrial network.[188] Moreover, by importing small turbines from

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[187] Chin-sung Chiu, *The Present Situation and Prospect of Wind Energy Utilization*, Industrial Technology Research Institute (Hsinchu County, 1982).

[188] Despite TPC’s wind project, Eugene Chien and Robert R. Hwang, an aeronautic engineer and a hydro science engineer respectively, used to conduct 325 kinds of simulation of the performance of wind blades in wind tunnel in 1974; Agricultural Engineering Research Center also underwent demonstration projects during 1975 and 1980 on vertical axis wind turbines equipped with Savanius Rotor, Darrieus Rotor, or Propeller type.

the U.S. to their test field to further collect the actual performance data and make improvements, the lab also aimed to nurture new talents at the site.[189]

After inquiring with Dr. Du Kuo-ji, who was then affiliated at the Rocket Flats Small Wind Systems Test Center in Colorado, they selected two American companies' products, Enertech's E-4000 (downwind turbine rated at 4kW) and American Energy Savers' No.5-24 (upwind turbine rated at 5kW), as their first research objects.[190] As soon as they completed the experiments on the two turbines, the lab launched the self-made 4kW wind turbine project in 1983. The so-called ITRI-WT-1 comprised a three-blade downwind type sail wing rotor, an induction generator with speed-up gearing, and a tower supported by wires.[191] They chose the most accessible and relatively inexpensive components in terms of the domestic market in order to make the turbines easily installed by household users. This framework suggests a significant turning point in Taiwan's wind power development from manufacturing large-scale turbines to small wind systems.

ITRI's and TPC's efforts in developing wind power primarily lay in the two organizations visions for how wind energy would contribute to Taiwanese society – with TPC focused on the energy system and ITRI more on manufacturing. Aiming to create an industrial network for small wind systems, ITRI transferred the manufacturing experiences from the reassembling of the imported turbines but also from the setup of the test center. On the other hand, ITRI's goal was to link up the value chain, including designing and manufacturing the wind energy conversion system, blades, transmission system, monitoring system, the tower, and transferring the techniques to the corresponding local factories for commercialization. Nevertheless, only Tung Hsing FRP Corporation and Yng Hung Electric Industry Co. Ltd. received technical assistance in manufacturing rotor blades and 40kW wind turbines, explaining the limited spillover effects at the time.[192]

Even though ITRI was able to assemble and test upwind horizontal axis wind turbines rated at 40 KW and 150 KW by 1991, for which local manufacturers made around 80 percent of the parts and components, local manufacturers could not make the most easily worn-out element, the gearbox.[193] The difficulties in advancing the crucial part and reducing the construction cost for large-scale turbines meant the testing site was deserted when the project

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[189] Chin-sung Chiu et al., *農田灌溉用及發電用小型風力機試驗及示範計畫 [Small wind turbine test and demonstration plan for farmland irrigation and power generation]*, ITRI (Hsinchu County: ITRI, 1981).

[190] The Rocket Flats was a national small wind systems test center initiated in 1976 for under 100 kW design. See *First Semiannual report, Rocky Flats Small Wind Systems Test Center Activities*, DOE Rocky Flats Plant (Golden, Colorado, 1978).

[191] Chin-sung Chiu et al., *Preliminary Design of ITRI-WT-I 4KW Small Wind Turbine System*, Industrial Technology Research Institute (Hsinchu County, 1983).

[192] *Energy Research and Development Fund Research Results - Wind Turbine*, Industrial Technology Research Institute (Hsinchu County: Ministry of Economic Affairs Energy Commission, 1991).

[193] Wei-jun Jiang, "追風歷程：我國風電發展沿革 [The journey of chasing wind: the development history of wind power in our country]," (2008). https://magazine.twenergy.org.tw/Cont.aspx?CatID=&ContID=1311.

ended. The formation of the Taiwan Wind Energy Association had to wait until the national renewable energy policies were promulgated during the 2000s. As the later discussion about this policy turn will show, compared to the various solar advocates' endeavors in lobbying for the Renewable Energy Development Act, the German wind power developer, Infravest, was the sole representative of the wind power industry. As the pro-renewable coalition has grown since the 1980s but not yet gained enough power to change the TPC’s expansion logic, TPC has managed to keep extending the carbon-intensive network. However, in the mid-1980s, TPC faced strong opposition to the fourth nuclear power plant while solar, wind, and geothermal remained small-scale and situated at the margins of the TPC system. Instead of moving decisively in the direction of renewables, TPC tried to maintain the carbon-intensive status quo by importing natural gas and by incorporating co-generation units to support peak load. As the next section will show, this strategy resulted in Taiwan’s first stage of market deregulation and had the unintended consequence of providing new opportunities for renewable development.

4.1.2 Market deregulation in the 1990s as a response to TPC's disrupted expansion

In 1988, the Industrial Bureau launched a promotion program for co-generation system installations. Combining waste heat or steam from the factories' boilers with gas turbines, the co-generation units can generate electricity as a side-product of the manufacturing process. In turn, energy-intensive users could produce power by themselves and help to achieve energy efficiency to ease TPC's burden of cross-regional power supply. At first, the 1988 program did not provide sufficient incentives to private industries due to the low power purchasing rate and the unsettled permission of IPPs.[194] After a series of meetings between TPC and the Industrial Bureau, the 1991 adjusted program proposed to set a premium price for the purchase within 20 percent of the co-generation power production and let TPC establish Taiwan Co-generation Corporation (TCC) through a joint venture. TPC's chief engineer at the time was the first chair of TCC in 1992. With TPC's leadership, purchasing power from co-generation units soon grew from 2.78 MW in 1990 to 37.99 MW by 1999, equivalent to the number of pumped-storage units that also meet peak loads. In short, through the 1990s TPC's network continued expanding by strengthening its ties with the energy-intensive users operating decentralized co-generation units.

Furthermore, the ensuing first deregulation of 1995 allowed energy-intensive users to become IPPs by deploying coal- or natural gas-fired generators in private factories for self-usage or selling to TPC via a 25-year Power Purchase Agreement. Nine IPPs were approved for operation through three stages of bidding and evaluation processes by the end of the 1990s. Taking Mai-Liao Power's three 600 MW coal-fired generators as an example, its investors were

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[194] "能源政策 [Energy Policy]" *經濟部 [MOEA]*, Academia Historica Collection, no. 031-050000-0040, Academia Historica.

Formosa Plastic Corp., Nan Ya Plastics, Formosa Chemicals & Fibre Corp., and Formosa Petrochemical Corp. Located at the controversial Sixth Naphtha Cracker Complex in Yunlin County in central Taiwan, the Mai-Liao power plant sits alongside sixteen co-generation units installed at the plants of the Formosa Petrochemical Corp. Together, the Formosa Plastic Groups owned Taiwan's largest IPP and co-generation plant.

As mentioned in the second chapter, petrochemical industries became the most significant industrial power consumer in 1967. Allowing co-generation turned those intensive users into private power producers, which enabled the carbon-intensive network to continue to expand into the 2000s. For TPC, such measures could make its dispatching schedule more flexible in controlling the allocation of available capacity from the IPPs, as TPC's development agenda was somewhat blocked at the time. From the demand side, the additional generators could increase petrochemical firms' energy independence and prevent economic losses due to system blackouts. At first sight, it might seem as though deregulation threatened TPC's monopoly position in the 1990s; but a closer look at TPC’s strategies reveals that the carbon-intensive network was entrenched thanks to co-generation units for existing energy-intensive users and the newly built natural gas pipelines across the island. In turn, the power consumption structure did not change much in the 1990s. However, TPC's ideal energy future again faced obstacles when the DPP first won the presidential election in 2000 with a mandate to think about harnessing renewable energy on a larger scale.

The conventional explanation for the shift in Taiwan's energy policy toward renewables stresses the impacts of the new international protocols of the 1990s.[195] However, ITRI's response to the UN Framework Convention on Climate Change in 1992 shows that international protocols were not much of a factor. ITRI's energy lab thought it was unfair and impossible for Taiwan to commit to reducing CO_2 emissions to the 1990 level by the year 2000 given that Taiwan's per capita carbon emission was only half that of the OECD countries.[196] As for TPC's part in such efforts, TPC's decarbonization strategies only suggested utilizing nuclear power plants and gas-fired generators as TPC began to import natural gas in the late 1990s.[197] Renewable energy had no place in Taiwan's decarbonization plan back then. So if renewables were not intended as a way to tackle climate change in response to international diplomacy, then what were they intended for?

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[195] See for example, Hwa-meei Liou, "Policies and legislation driving Taiwan's development of renewable energy," *Renewable and Sustainable Energy Reviews* 14, no. 7 (2010): 1763-81.

[196] "抑制二氧化碳排放之能源策略研究 [Research on energy strategies to curb carbon dioxide emissions]" *經濟部 [MOEA]*, Academia Historica Collection, no. 031-030000-0014, Academia Historica.

[197] "行政院科技顧問會議「全球氣候變遷之因應策略」（三）[Executive Yuan Science and Technology Advisory Meeting "Response Strategies for Global Climate Change" (3)]" *經濟部 [MOEA]*, Academia Historica Collection, no. 031-030000-0011, Academia Historica.

4.2 Nuclear versus Renewables?

Worldwide, post-Chernobyl nuclear disputes in the 1990s became a significant factor in justifying the R&D shift to renewable energy development.[198] Likewise, the safety and environmental concerns of the nuclear power plant and waste disposal had far-reaching influences in deepening Taiwan's political cleavage and stimulating renewables development. Renewable energy gradually came to be framed as the most promising solution to the questions of nuclear power and decarbonization, but not in the early 2000s as yet. When the DPP's candidate took over the administration for the first time in 2000, the Cabinet launched a promotion program for installing onshore wind power systems and expanded to a more comprehensive ten-year development plan in 2002. Moreover, at a cabinet meeting in 2003, the Minister proposed to increase renewable energy's share in the total installed capacity from 5.7 percent in 2003 to 10 percent by 2010, with wind power (including onshore and offshore wind turbines) the primary means to reach the policy goal. Based on their projection, the accumulated installed capacity of wind power was supposed to reach 2.15 GW by 2010.[199]

From the earlier discussion, it became clear that TPC was not engaged in the solar business as the network started to emerge in the 1980s. But with TPC’s wind power systems having already been displayed at larger scale at Qimei Isle, the DPP government chose wind power demonstration projects over solar to lead TPC’s renewable energy program. As the next section will show, since TPC was more familiar with the development pattern of utilizing existing allies (such as the IPPs), these were the first groups of local actors engaged in the wind business. Incorporating wind turbines at the margins of its system, TPC could continue its development path, all the while hoping to eventually resume construction of its fourth nuclear power plant. A year before the 2000 presidential election, the issue was again brought up in the parliament as the AEC approved the construction permit.

In the preceding chapter, I explained how the nuclear issue was embedded in the competition between the two major political parties, KMT and DPP, since the late 1980s. Even though DPP finally grasped the power to formulate energy policies, the KMT still controlled about half of the parliament in the early 2000s, making the cabinet's plans, especially on those sensitive issues, more difficult to set into motion. The elected President Chen Shui-bian's cabinet delivered its promise and once again suspended the budget for the fourth nuclear plant. In response, the KMT lamented that the cabinet violated the Constitution because the decision was not first presented at the parliament; by bringing the case to the Constitutional

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[198] After the Chernobyl meltdown, the first World Renewable Energy Congress took place in 1990 to address the prominent future with renewable energy as remedy to the fluctuate oil prices and nuclear issues. The following establishment of the *Renewable Energy* journal also signifies the growing concerns against nuclear power usages while renewables were mostly treated as alternative options. See A. A. M. Sayigh, "Editorial," *Renewable Energy* 1, no. 1 (1991): i.

[199] Wen-jyh Yan, "The development and prospect of wind power," *Monthly Journal of Taipower's Engineering*, no. 705 (2007): 1-8.

Court, the KMT legislators successfully forced the budgetary bill to resume in 2001. After a month-long consultation among the political parties, they came to the resolution that while the construction went back on track, the opposition parties would agree to DPP's vision of a "Nuclear-free homeland" on a long-term basis.[200] For TPC, the controversy delayed but did not derail their plans for completing their largest nuclear power plant with two units rated at 1.35 GW.

Compared to the consensus within each party on either a pro- or anti-nuclear power position, the legislative process of the government's subsidies scheme for the renewable energy industry clearly shows much more diverse opinions within each party. From a Cabinet draft to official promulgation, the renewable energy bill underwent seven years (2002-2009) of evaluation in parliament, in which lobbying groups and DPP advocates realized that the better way to forge consensus despite their party's preference was to frame their aims as falling under the umbrella term of sustainability.

Looking to the German government's Renewable Energy Act for a model, which had just come into force in 2000, the Cabinet drafted the first version of the renewable energy bill in 2001 and tried to copy the power purchase scheme of a fixed feed-in-tariff for 20 years to increase the economic incentives for market entry. However, parliament did not go along with the cabinet's plans. According to the secretary of the leading lobby group, the New Energy Association of Taiwan (NEAT), the KMT legislators did not want to back the DPP's policy after the heated debate on the nuclear issue. Gathering together the German Infravest, Taiwan's solar power companies, and think tanks, NEAT members reached out to the KMT and the pan-KMT party legislators to formulate their versions of acts to put the bill on the legislative agenda in 2002.[201] Even inside the DPP, there were different voices regarding how the rate should be set and the financial sources behind the subsidies for such measures would bring both considerable revenues and costs to certain industries.

As for TPC, TPC argued that the large-scale penetration of renewable energy with its intermittent nature would hinder power stability and cause a massive loss for semiconductor manufacturers. TPC's framing was an attempt to mobilize the Taiwanese government's most-favored industry (and TPC's soon-to-be primary power user) to block the bill. Nevertheless, the possible exchanges of benefits between renewable industries and legislators exceeded party divisions. A cross-party alliance for passing the bill in the parliament emerged based on their mutual interests in facilitating Taiwan's sustainable development. For example, one of

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[200] "行政院函告所屬相關部會，有關核能四廠復工事宜。[The Executive Yuan issued a letter to relevant ministries and councils regarding the resumption of work at the fourth nuclear power plant.]" *核能四廠釋憲案 [Constitutional Interpretation of the Fourth Nuclear Energy Plant]*, Digital Archive, no. N/A, Assembly Affairs Museum, The Legislative Yuan.

[201] Zhi-chun Zou, "A study on the legislation process and execution of the Renewable Energy Development Act in Taiwan (R.O.C.)" (EMPA Master thesis, National Taiwan University, 2011).

the initiators of the alliance had a close relationship with the NEAT and participated in numerous environmental protests before entering the parliament.[202]

By 2009, when KMT resumed power, the parliament had agreed to leave the controversial rate decision in the hands of a specialized task force chaired by the Energy Bureau and passed the bill without an actual amount of the feed-in-tariff on it. For the carbon-intensive network, the Renewable Energy Development Act increased the generation cost by requesting that the existing co-generation units, IPPs, and TPC's conventional thermal and nuclear power plants allocate a certain amount of fees to the renewable energy fund. The Act also stimulated rapid growth of wind turbine installation by the German wind power developer Infravest as they could finally redeem their efforts in pushing through the bill with the NEAT. In short, the birth of the Renewable Energy Development Act in 2009 indeed reordered the priority of Taiwan's energy choices, but still, harnessing renewable resources was not an act of seeking substitutes.

It was the subsequent Fukushima incident that provoked a rising tide against the pro-nuclear KMT government in 2011 that shaped the rival relationship between renewables and nuclear power. In response to Fukushima's nuclear meltdown, the Ma Ying-Jeou administration (2008-2016) announced the OWE program under the policy framework of the "Thousand Onshore and Offshore Wind Farm Program" to cope with public pressure while maintaining ambiguity about the decommissioning of nuclear power. When power was handed over to the DPP in 2016, Tsai Ing-Wen's reiteration of a "Nuclear-Free Homeland by 2025" reframed OWE as a substitute rather than one of the add-in options. In other words, OWE was given different missions by the two main political parties: a supplemental role under KMT's "steadily decarbonized" policy (which still heavily relies on nuclear power) and a means to achieve energy justice under DPP's "energy transition" policy toward a zero-nuclear energy future.

Under the DPP, renewable energy technologies were then bearing the ambitious goal of phasing out nuclear power with the existing conventional generators – fossil fuel-based thermal power plants. To facilitate such change, the DPP government pushed through an essential amendment of the Electricity Act in 2017, which approves renewable companies (instead of other types of IPPs) to sell directly to the end users, which means a further step toward market deregulation. Allowing them to join the retailers and sign power procurement agreements (PPAs) with extensive consumers helped increase the economic incentive to attract more private developers into the business. Moreover, the Act requests TPC to divide its generation, transmission, and distribution businesses into several electricity-generating enterprises and an electricity transmission and distribution enterprise as subsidiaries by 2023.

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[202] Zou, "A study on the legislation process and execution of the Renewable Energy Development Act in Taiwan (R.O.C.)."

2017 signified Taiwan's substantial turn toward renewable transition, but the power struggles among parties continued.[203]

After 2011, in Taiwan's parliament and public debates, renewables development became more closely intertwined with the controversial nuclear units. In the following referendums of 2018 and 2021, the energy-related proposals ranged from the choices between nuclear or renewables, whether to operate the fourth nuclear power plant or not, and whether or not to build another coal-fired power plant and a liquified natural gas terminal. In other words, Taiwan's energy dilemma was rooted in the same problem as in the 1980s: how to restructure the carbon-intensive network with or without nuclear power units. The only difference is that renewable energy technologies have made the problem more complicated. For example, "go nuclear to go green" is a catchphrase coined by pro-nuclear activists that framed renewable energy as an "unstable" electricity-generating technology in its infancy during Taiwan's 2018 referendum. They suggested that renewables' development would have to rely on a relatively constant output of nuclear power to help Taiwan's power structure reduce fossil fuel usage and achieve decarbonization. Supported by KMT, they successfully collected enough signatures to support their proposal of abolishing Section 1 of Article 95 of the Electricity Act, which envisions terminating all nuclear power plants by 2025. At the end of the votes, the proposal was passed with 40.27 percent approval which was directly in opposition to DPP's envisioned "Nuclear-Free Homeland by 2025."

Moreover, the result also sabotaged Taiwan's ongoing offshore wind energy development. After the referendum, the public pressure on the Government's renewable subsidization of the feed-in-tariff for OWE led to a halt of OWE developers’ investment decisions in early 2019. Although eventually the developers came around, the episode suggests that the potential overturns of policy support might slow down the phase of Taiwan’s energy transition. On the path of renewable transition, Taiwan’s case exemplifies how energy choice, and the ways energy resources are exploited in practice are intrinsically political and involve a series of negotiations.

The following section first looks into the onshore wind projects in which harnessing wind is the vehicle for the central government's commitment to try alternative options besides nuclear power. The later scaling up and turn toward offshore wind further represents the national aim to decarbonize Taiwan's economy and achieve energy independence. However, the cases will show how the existing carbon-intensive network undermines those projects' potential to bring changes to the TPC system and the local societies. Furthermore, I will discuss TPC's countering strategies toward the system impacts of the growing renewable penetration since the 2010s to argue how Taiwan’s current path of energy transition might be more about continuity instead of a break with its carbon-intensive past.

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[203] See Section 1 of Article 6 of the Electricity Act amended on January 26th, 2017. https://law.moj.gov.tw/LawClass/LawOldVer.aspx?pcode=J0030011

4.3 Wind questions onshore and at sea: understanding renewable development at the local scale

4.3.1 Decentralized land-based wind turbines

In the early 1990s, replacing the easily worn-out gearbox with a direct drive design in which the rotational speed is directly fed into the generators became possible.[204] Such turbines could help solve the maintenance problem at distant sites and, thus, were broadly applied in Taiwan's demonstration projects. However, it remained challenging to erect multiple wind turbines in a short period without much manufacturing or operational experience in MW-level wind turbines, resulting in high barriers for private investors and dependence on foreign developers. Even with the Energy Bureau providing subsidies to wind power demonstration sites, only three companies stepped into the arena, namely TPC, Formosa Heavy Industries Corp. (FHIC), and Cheng Loong Corp. That is, TPC and the carbon-intensive users remain the significant players in Taiwan's electricity market even if renewable units were the development target.

The experimental nature of these projects could be seen from the fact that none of these wind turbine generators were put into connection with the TPC grid. The first demonstration site was finished by the FHIC. Except for the direct drive type turbine and monitoring system (which were imported from the Danish company Vestas), the other parts, such as the tower and cable layout, were designed by FHIC themselves or purchased from local manufacturers. FHIC's will to invest in decentralized units stemmed from its desire to supply electricity to its energy-intensive petrochemical business. Therefore, like FHIC's construction of the Mai-Liao Power plant, the four wind turbines rated at 660 KW were built in the same petrochemical complex in Yunlin County. In so doing, the FHIC could avoid troubles arising from land acquisition. The same thing was true of Cheng Loong Corp.'s site, which was built inside the company's factory with two imported direct-drive type wind power systems from Vestas.[205]

As the direct drive turbines reassured TPC's worries regarding their past operation and maintenance failures, TPC returned to Penghu in 2000 with the support of the government-funded demonstration program. TPC first built four turbines rated at 600 KW at Chuton village and added another four of the same size in 2004 with a direct connection to Penghu's baseload thermal power plant. Later, the same pattern was transplanted to Formosa Island as they built wind turbines at their nuclear stations and thermal power plants under the "Thousand Onshore and Offshore Wind Farm Program" in the 2010s. However, as commercialized MW-

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[204] Geerten van de Kaa et al., "Wind turbine technology battles: Gearbox versus direct drive-opening up the black box of technology characteristics," *Technological Forecasting and Social Change* 153 (2020): 119933.

[205] See the project introduction on the website of the Single Service Window for Wind Power, under Energy Bureau, Ministry of Economic Affairs. https://www.twtpo.org.tw/onshore_list.aspx?category_id=58&cat_id=61

level wind turbines grew rapidly on the coastline in sight, they provoked a massive protest concerning their distance to residential areas. Wind resources might be relatively inexhaustible, but the land that turbines occupy is not.

The most well-known case is the demonstration against the visual disturbance and noise nuisances from the German developer Infravest's wind sites during 2012 and 2014 in Miaoli County. Against InfraVest's partially informed decision to erect 14 wind turbines near the residential neighborhood, the local farmers, residents, college professors, and students joined the Yuanli Self-Help Group in urging the government's involvement to regulate a standardized "safe distance." The Group stressed that they were not objecting to the national renewable policy but against the so-called "wind turbine syndrome," such as sleep disturbance, nausea, or dizziness caused by the low-frequency sound from the wind turbines. After a series of controversial episodes, InfraVest suspended the construction of the disputed two turbines, but the issue of land utilization and the benefits that renewable development could bring to the local communities lingers on.[206]

Take Penghu as another example. The central government poured around NTD$ 8.09 billion (approximately equivalent to USD$ 355 million today) into turning the offshore islands, which mainly relied on fuel oil-fired generators and several wind turbines, into Low-Carbon Islands in five years (2011-2015). Such considerable financial support promised Penghu another opportunity to enhance its power infrastructure and grant new jobs. Promoting green energy became one of the Penghu Magistrate's central policy performances in subsidizing energy-saving appliances, electrical cars and buses, and LED lights and installing wind and solar power systems to increase their share of total electricity generation to over 50 percent by 2015. Ideally, TPC should help to install MW-level turbines accumulated to 32 MW by then. Meanwhile, a local wind energy company, Penghu Energy Development Corporation, should be established to build and operate wind power systems of 64MW through joint ventures among Penghu County Government (25 percent share), Penghu citizens (30 percent share), TCC (25 percent share), and a wind power system builder (20 percent share).[207]

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[206] Taiwanese scholars have been working on similar issues regarding the Government's promotion policy of combining existing fishing ponds with solar panels. The ensuing developers' rent-seeking behaviours caused the rent continued to soar, and made the fishing ponds a site of competition between solar developers and fishermen. See Chiu, "漁電共生行不行 [Is Fishery and Electricity Symbiosis Feasible?]." Also, scholars had noticed the "land grabbing" phenomenon across case studies of renewable energy development. For wind power, studies on the wind parks in Mexico criticize the seemingly benign idea of green energy harnessing by detailing the ecological degradation and exploitations among vulnerable social groups. See for example Alexander Dunlap, "Wind, coal, and copper: the politics of land grabbing, counterinsurgency, and the social engineering of extraction," *Globalizations* 17, no. 4 (2020): 661-82; Alexander Dunlap, *Renewing Destruction: Wind Energy Development, Conflict and Resistance in a Latin American Context* (Rowman & Littlefield, 2019), 304.

[207] "總統馬英九視察臺電公司澎湖中屯風力園區（致詞稿） [President Ma Ying-jeou inspects Taipower Company's Penghu Zhongtun Wind Power Park (text of speech)]" *馬英九總統文物[President Ma Ying-jeou office archives and presidential artifacts]*, Academia Historica Collection, no. 080-010106-00436-001, Academia Historica.

In contrast to the players in the wind power business on Formosa Island, the birth of such an organization is important because it represents the first time the local government and residents could directly invest and participate in the energy business within the TPC system. On the other hand, Penghu Energy Development Corporation also represented a different mode of cooperation at local scale in terms of Taiwan's energy politics. Setting up the local energy company could bring residents into discussions about siting and possible compensation and feedback funds at the beginning of the project planning. In so doing, it might generate cooperation between the developers and users that differs from TPC's compensation scheme of Neighbouring Work and avoid the conflicts at InfraVest's wind projects. However, the Penghu energy company's expected revenue from selling wind-generated power surplus to TPC's grid on Formosa Island was blocked by the delayed construction of TPC's undersea cables. TPC initially planned to finish the cables by 2015, but due to the unsettled fisheries compensations for the cables' possible impacts on the fish stocks in the coastal areas, TPC encountered strong protests since the project's launch in 2011.[208] By the time TPC finally got the construction permission in 2018, the Penghu Energy Development Corporation had already dissolved in 2015, and so did the MW-level wind power systems projects.

Taiwan's onshore wind power development exemplifies how it represents an opportunity to involve diverse actors and interests in the discussion. Although even if the Penghu Energy Development Corporation did manage to survive, there would still be problems of energy injustice because it would be exchanging their scarce land to build up turbines for the green electricity transmitted to the Formosa Island.[209] Nevertheless, the importance of TPC's submarine cables in Penghu's case indicates that in practice, the cables matter not only for turning Penghu "green" or interconnecting Penghu's originally isolated power grid to TPC's system to ensure a stable power supply but also for the installation to bring money, political power, and resources to the local communities.

Decentralized power units are often praised for their perceived potential to empower users by shifting their roles from consumers to producers and increasing energy efficiency without long-distance transmission. Yet, Penghu's case shows that in Taiwan, the benefits accompanying the wind-generated electricity flow are not community-based and still

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[208] Jing-fen Ji, "電網展新頁：16 年 67.9 公里，穿越海峽的那道光 [New page of the Power Grid: 67.9 kilometers in sixteen years, the light crossing the strait]," *TaiPower Journal*, no. 709 (2022): 6-11.

[209] The concept of energy justice involves ensuring fair and equitable participation in energy-related decision-making and distribution of benefits. In this context, the issue of energy injustice arises from the exploitation of land resources on Penghu Island for the purpose of constructing wind turbines. This has sparked debates at the local level regarding the compensation arrangements in exchange for the renewable energy that would be supplied to TPC's grid on the main island. Insightful work that details how an island being treated as test field and power bank to serve national aims, see Laura Watts, *Energy at the End of the World: An Orkney Islands Saga* (MIT Press, 2019), 440.

significantly rely on the interconnection to TPC’s primary power grid, which yields more substantial influence at the local level, also in terms of conflicts.[210]

Another point to be noted is that the three demonstration projects and Penghu's ensuing failures suggested that wind turbines could only work by integrating into the existing TPC system. They were deployed either in the factories for self-use or in connection with thermal or nuclear power plants instead of directly providing electricity for nearby residents. Aside from the benefit of avoiding land disputes, placing wind turbines beside TPC's large-scale power plants helps to prevent further troubles for TPC to upgrade its networks, such as increasing the number and capacity of their feeder lines and transformer stations.

Solar power units cover Taiwan's central and southern regions thanks to higher levels of insolation and are mostly interconnected to the distribution network at 11.2 or 22.8 KV. In contrast, onshore wind turbines on Formosa Island feed power through transmission lines at 69KV, the number and locations of which are more limited in the cities and even in the mountain areas. Moreover, if the site is far from the 69 KV lines, wind developers are requested to build their own 22.8 KV feeder lines to connect with TPC's distribution stations or 161KV transformer stations, meaning a substantial increase in their total construction and maintenance cost per site. Such structural limits also bound the locations of wind turbines enclosed by industrial areas. For example, InfraVest's largest wind project, comprised of three sites, resides inside the Changbin industrial zone in Changhua County, with a total of 42 turbines rated at 2.3 MW per unit. In short, access to TPC's grid at a given voltage level pre-determines Taiwan's wind technology's potential to benefit remote islands or villages in the mountain areas to achieve energy independence; or its possible contributions to enhancing the TPC system's regional balance of supply and demand. The transformation of the system is as vital as the share of renewable energy. After the 2017 amendment demanded a structural change of TPC itself in the near future, OWE's concurrent development further stimulated TPC's transformation with the proliferating controversies.

4.3.2 Turning seaward: Measuring the invisible offshore wind, fish stocks, and political interests

Although the Taiwanese Government introduced OWE into its policy outlines in 2011 to respond to the Fukushima accident and launched the promotion programs for OWE's demonstration projects the next year, the Government has been allocating funds for relevant research since 2001 (Figure 17). However, it was not until 2007 that the Government considered connecting OWE to the power system. The first sophisticated research plan assessing OWE's feasibility was led by Yeh Chau-shioung, who specializes in applied mechanics

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[210] Paul Jobin, "Our ‘good neighbor’ Formosa plastics: Petrochemical damage (s) and the meanings of money," *Environmental Sociology* 7, no. 1 (2021). Paul Jobin, "Our ‘good neighbor’Formosa plastics: Petrochemical damage (s) and the meanings of money," *Environmental Sociology* 7, no. 1 (2021): 40-53.

and earthquake engineering. Recognizing Western Taiwan's coastline's geographical and meteorological features, including its loose, sandy seabed with frequent earthquake and typhoon activities that differ from Europe's, Yeh and his fellow researchers soon realized that implementing OWE would require a longer view than indicated by rough estimates in laboratories.[211]

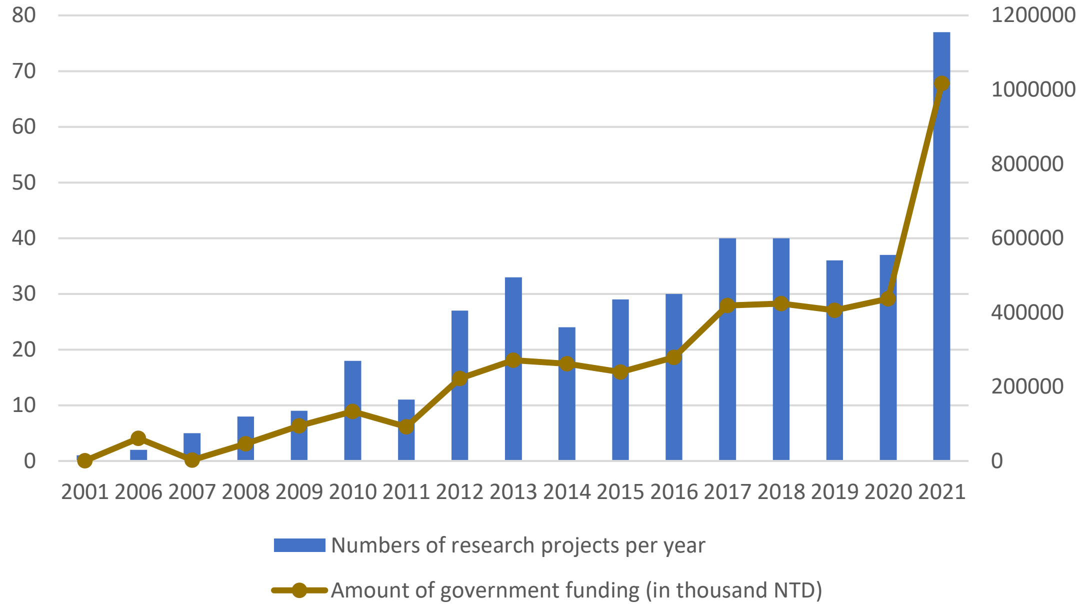

Figure 17 Numbers and amounts of government research funding in OWE-related research from 2001 to 2021.

Source: Data extracted from the Government Research Bulletin.

The same importance of meteorological data on wind speed and directions would affect land-based wind turbines' performance and operation. These researchers point out that sufficient meteorological and oceanographical measurements in offshore waters are necessary for deciding the bidding areas and the OWF's layout and turbines' feasibility. These decisions would lead to further questions about how to visualize and quantify the ecosystem before and after OWE's interference, which is the sticking point amid the conflicting interests of the fishery economy and marine ecology. Due to the overlapping areas with fishing grounds, utilizing offshore wind becomes an issue of rearrangements and reassessment of Taiwan's fishing activities.

The unsolved questions soon escalated to protests that delayed the construction works of the pioneering OWE demonstration project. Located outside the fishing port of Miaoli County, Taiwan's first demonstration project of OWE, Formosa I&II, was initiated in 2013 by Swancor, a Taiwanese chemicals manufacturer that produces epoxy resin and hardener for the

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[211] Chau-Shioung Yeh and Chun-To Tso, *台灣離岸風能發電國家級研究計畫-先期規劃計畫 [National Offshore Wind Power Program: Pioneer Project]*, Department of Civil Engineering, National Taiwan University (National Science Council, Executive Yuan, 2007).

wind turbine blades. With the government providing subsidies, two turbines, and one meteorological mast were built in Miaoli County's territorial sea and put into operation in 2017. Simultaneously, negotiations began for the compensation and arrangement of the overlapping marine space among the developer, fishermen’s association, Energy Bureau, Fisheries Agency, and local government. Swancor ended up increasing the compensation amount from NTD$ 1.8 billion to 3.05 billion after meeting with the elected committee of the Nanlong Area Fishermen's Association. However, the deal was designed to allot the amount to 325 fishers in the Nanlong area while the wind turbines would be installed much closer to the Long Fong Fishing Port than Waipu Fishing Port. Although there were no exact demarcated areas in the Nanlong waters, fishers were bound to a specific fishing port depending on their boat size and fishing gear, which resulted in a distinct working schedule and ground. Therefore, neglecting such divergence within the fishing community led to the gillnet fishers' protest for renegotiation.[212]

Fearing that the same situation would occur at other OWE sites in the future, a communication platform was established in 2015 and convened by Ou Ching-hsiewn. Ou is the ideal figure for his long commitment to studying and improving Taiwan's fisheries management. Also, he had experience as a mediator delegated by the Energy Bureau in negotiations between the OWE developer and the local fishermen’s association in another demonstration project in Changhua County. Gathering experts in fisheries impact assessment, representatives of fishermen’s associations, and related officials from administration authorities, the platform held several meetings in 2015-2018 to generate consensus and drafted a formula for fishery compensation. Based upon Ou's research team’s fishery surveys across different districts on fishery species, fishing methods, spatial and temporal characteristics of fishing ground, and catch-per-unit-effort (catch rate), the official formula was later announced in 2016. Since fishers tend to underreport their actual catches to avoid competition in certain fishing areas, Ou expressed the difficulties for Fishery Agency alone to have thorough records on fishing types or catches of coastal (less than 12 nautical miles) and offshore fisheries (between 12 to 200 nautical miles). The formula is created to ease the tension between developers and fishermen while fixing the problem of bargaining through private channels, which might hinder Taiwan's OWE development in the longer term.

Aside from calculating the possible fishing loss, the impact on society was quantified in the settlement of the feedback fund. Accordingly, the platform also helped generate a framework of feedback funds based on TPC's scheme of Neighboring Work. Since the claimed amounts of the fund are determined by the distance to TPC's facilities, TPC's scheme does not fully apply to OWFs in deep waters. The gray area becomes the center of arguments in the

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[212] Jian-li Peng, "30 漁船集結 抗議風機補償分配不公 [30 fishing boats gather to protest unfair distribution of wind turbine compensation]," *Liberty Times Net*, May 24 2015, https://news.ltn.com.tw/news/local/paper/883035.

meetings. OWFs might not be in sight, but the submarine cables, their transition point onshore, and the transformer station required to be integrated into the TPC's grid will be. A representative of the Miaoli County Government gave an example in the meeting to explain how valuable such a fund is to the County Government. Because of the planned installation of new gas turbines at TPC's Tunghsiao power plant, TPC provided NTD$ 1 hundred billion to obtain their consent, while the government's fiscal budget is only around 19.7 billion.[213] In the end, the feedback fund is set to be shared by the regional fishermen's association (55 percent), the township where the transformer station is located (30 percent), and the county/city government (15 percent). At the municipal level, welcoming offshore wind developers means an opportunity to enhance infrastructure improvement and economic progress with their considerable investments and funds. Perhaps more importantly, these financial aids can be distributed down to the administrative level of townships and village offices. On shore, these actors tried to align the possible stakeholders under the compensation scheme to generate consensus; at sea, developers also strived to build allies through other strategies to tackle the marine spatial conflicts.

The Danish developer Ørsted entered the market in 2016. After one year of research, Ørsted sent out the EIA report with brief outlines of OWF's design in 2017. In the original plan, Ørsted planned to install wind turbine generators (WTGs) per capacity of 4 to 11MW with either a monopile or jacket foundation. These are the most common types of underwater support structure: for a monopile, a single steel tube is drilled into the seabed, usually in shallow waters; for a jacket foundation, multiple steel tubes are deployed in a lattice framework at the sea floor with a transition piece to connect to the wind tower. The range of installed capacity and substructure was expected to achieve economic scale and withstand severe environmental conditions for at least 20 years. However, the absence of longitudinal data on fishing activities, sea conditions, and biodiversity in offshore waters left the spatial conflicts between researchers, fishers, migratory birds, and marine mammals (especially the endangered species of *Sousa Chinensis taiwanensis*) unsettled. With the joining of OWF, the power struggle at sea was brought to light.

Throughout the six EIA meetings during 2017–2018, Ørsted rearranged the components to ease the tensions. First, Ørsted encountered significant criticism regarding acoustic pressure on *Sousa Chinensis taiwanensis* (a subspecies of the Indo-Pacific humpback dolphin) and collision risk with seabirds from environmental NGOs, including the Changhua Environmental Protection Union, Matsu's Fish Conservation Union, and the Wild at Heart Legal Defense Association. Also, there were doubts about the possibility of decreasing fish stock from the

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[213] Ching-hsiewn Ou, Studies on the coordination between offshore wind farms and fishery activities and the spatial planning of friendly fishery I, 2016, MOST 104-3113-F-019-001, National Taiwan Ocean University Department of Environmental Biology and Fisheries Science.

perspective of the Changhua Fishermen's Association. If we took the stakeholders' viewpoints separately, the OWF seemed to be the main culprit that damaged marine ecology.

It is essential to note that before introducing OWE to Changhua County, the unintentional bycatch of gillnet fishery and vessel strikes have been reported as the primary causes of the declining species in coastal waters of less than 20 m depth. [214] As for the worries about the possible loss of fish resources, since there is no accurate record of fish caught, identifying the original number and its variance is a gray area. Surveys show that Changhua fishers who apply trawling methods were more concerned about the provocative intrusions of Chinese fishing boats and industrial wastewater pollution from the Changbin industrial zone. According to the claims from zoologists, environmental NGOs, and fishers, the power struggles at sea among humpback dolphins, marine biodiversity, and fishery activities are pre-existing. They have been left in limbo without credible data, efficient fishery management, and law enforcement. As a representative species in Taiwan’s context, understanding humpback dolphins' situation and the offshore wind developers' dealing strategies will help explain how renewable transition entails more than just the changing numbers of the energy mix.

Following the nutrient-rich groups of zooplankton in the Kuroshio branch current from the south, *Sousa Chinensis taiwanensis* chases its prey to the shallow waters along the western coast. The warm current contributes to the rich marine ecosystem while providing an abundant fish stock for the fishery. As a result, the anthropogenic stress that came from fisheries interactions and habitat destruction seriously affected its survival rate. The Taiwanese humpback dolphin was officially recognized as an endangered species on the International Union for Conservation of Nature red list in 2008.

Because of the difficulty of "visualizing" the Taiwanese humpback dolphin population and distribution patterns without longitudinal data, it has been challenging to push forward conservation planning since the researchers became aware of their declining population from gear-entanglement or stranding cases in the 1990s.[215] Even though large-scale protests against the reclamation plan of the Kuokuang Petrochemical plant in Changhua had made *Sousa Chinensis taiwanensis* a household word, a decade later the Taiwanese Government has still failed to facilitate effective preservation measures due to tremendous pressure from the local fishermen.

Ørsted's attempts at solving the invisibility problems of humpback dolphins by enhancing their surveillance network show one of the innovations that OWE brought into Taiwan's marine spatial planning. The intrinsic materiality of WTGs offers a fixed observation point in

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[214] See for example, Claryana C Araújo et al., "Viability of the critically endangered eastern Taiwan Strait population of Indo-Pacific humpback dolphins Sousa chinensis," *Endangered Species Research* 24, no. 3 (2014): 263–71; Wei-lun Chang et al., "Reproductive parameters of the Taiwanese humpback dolphin (Sousa chinensis taiwanensis)," *Regional Studies in Marine Science* 8 (2016): 459-65.

[215] Chi-mao Wang and Ker-hsuan Chien, "Mapping the subaquatic animals in the Aquatocene: Offshore wind power, the materialities of the sea and animal soundscapes," *Political Geography* 83 (2020): 102285, 1-9.

offshore waters and a marine protection zone in terms of ecological restoration. First, Ørsted planned to arrange WTG as an offshore observatory to collect at least 20 years of longitudinal data regarding meteorology, migratory birds' seasonal flying patterns, and fish aggregation effects. For example, fish species abundance and distribution on-site will be investigated once every season and 20 times per year for a cetacean survey. A thorough study of Changhua's fishery economy every year is also included in Ørsted's final EIA package. This marine database is built in cooperation with the nearby OWFs of Hai Long and Formosa III. It helps Ørsted to settle the argument by offering zoologists and NGOs the opportunity not to be bound to the limit of the research budget, as before, in their marine preservation advocacy. More importantly, the surveillance database setup means that the impact assessment does not end with the EIA meetings. The visualized marine environment with numbers and figures enables the establishment of the supervising group, in which the executive secretary of Changhua Environmental Protection Union is the vice-chairperson, to keep track of the ecosystem on a long-term basis. In so doing, it gains NGOs' support by involving them in the system.

Second, although Ørsted's survey showed that it does not overlap with Changhua fishermen's usual fishing area, trawling is the primary forbidden fishing activity. This fishing method of operating a trawling net on the seabed has the potential of entangling fishing nets with the substrate of the WTG. Still, the higher risk of gear entanglement and traffic congestion discourages fishing activities in general which might generate an ad *hoc* preservation effect. Closer to shore, the most controversial waters that are less than 12 nautical miles out are where the Taiwanese humpback dolphin struggles with gillnetting and angling fishing activities. Ørsted's contract with the Changhua Fishermen's Association imposes regulations, such as temporary closed-fishing seasons and measures to tackle the abandoned, lost, or discarded fishing gear to ensure the sailing safety of installation and operation vessels during construction season. In turn, the de facto fisheries exclusion indirectly eases the tension between fishing operations, the Taiwanese humpback dolphins, and other vulnerable species, such as the *Rhynchobatus australiae*.

Third, the increasing demand for Marine Mammal Observers and marine affairs regulations boosted a series of institutional changes. On April 28, 2018, the Ocean Affairs Council and Ocean Conservation Administration were established. Following the independence of regulatory authority, President Tsai promulgated Taiwan's first Ocean Basic Act to initiate a comprehensive framework for organizing marine resources, marine industry, and ecological preservation. With this institutional push, the Ocean Conservation Administration can exert effective measures for preservation, such as commencing the Major Wildlife Habitat of Indo-Pacific Humpback Dolphins and the official training system of the Taiwan Cetacean Observer in 2020.

In general, those above-mentioned large-scale socio-technological rearrangements seem to exclude fishing activities significantly. Nevertheless, it does not mean downplaying the role of fishery activities at sea. On the contrary, Ørsted aligned with the Changhua Fishermen's Association by strengthening the fishery infrastructure in exchange for their compromise. The following section elaborates on another critical change regarding OWE's development that happens at the intersection of their common interests, the harbor.

4.3.3 Linking up the network of the fishery economy and TPC’s carbon-intensive network

A harbor is an indispensable component for both the OWE system and the fishery economy. At the local level, as an infrastructure, harbor facilities bring in considerable investments, employment, and critical landscape changes to the city (or township), which turns into a rallying cry for local politicians' performances. "Seeing is believing," the incumbent Changhua County magistrate Wei Ming-Ku (2014–2018) reiterated in public interviews when talking about the reason his administration determined to make OWE's development one of his major policies for winning the next election.[216] On a field trip to England in the summer of 2017, they visited the Copenhagen Infrastructure Partners' Ormond OWF and Ørsted's operation and maintenance (O&M) base at Grimsby. Grimsby's case exemplified how a fishing harbor could attract massive investments and employment to transform the declining fishing community. Seeing the operating OWF and considerable investments in the fishing harbor, the Lukang township mayor noted that it represents what changes OWE might bring about to the local community. Their accounts further show how a harbor represents the intersection of economic flow and political interest. In exchanging the Changhua Fishermen's Association's consent and local policy support, Ørsted aligned their common interests by expanding fishing facilities and enhancing fishery governance accompanying OWE's development.

The Changhua Fishing Port, located at the southwestern reclamation ground of the Changbin industrial zone in Lukang township, is expected to follow the same path as Grimsby. The former chief of staff of the Department of Economic Affairs of Changhua County Government recalled that, in Wei's original blueprint, they were planning to turn the Changhua Fishing Port into the O&M base for OWF's crew training and transporting.[217] However, Changhua County Government's annual budget is mainly spent on educational and social welfare programs. The development of major transportation systems would have to rely on the central Government's financial aid. The Changhua Fishing Port case has been halted for years due to the shortage of funds since approved by the EIA committee in 2007. Centering on

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[216] The interviews including *Taiwan Hall of Fame*, "Changhua county magistrate, Wei Ming-ku," aired April 22 2018, on TTV. https://youtu.be/fuLCqtitgGc; *雲端最前線,* episode 385, "彰化縣長一任魔咒？魏明谷：破給你看 ", aired July 3 2018, on ETtoday.net. https://boba.ettoday.net/videonews/89785; *鄭知道了*, "魏縣長專訪," aired September 3 2018, on SETN.com. https://www.youtube.com/watch?v=szHAMAXYDLE.

[217] Interview with the Department of Economic Affairs of Changhua County Government's former chief of staff on August 20, 2020.

the Changhua Fishing port, Wei's administration looked forward to diversifying the fishing economy with OWE development, attracting foreign investments, and increasing local government revenue. In other words, the energy issue was entangled with local politics, the fishing economy, and the development of a sustainable marine ecosystem in Taiwan.

The Changhua Fishing Port's construction project not only bears the hopes for economic prosperity from the local Government's perspective, but the fishermen also longed for its completion. Other fishing ports are so far from the open sea that without the Changhua Fishing Port, fishermen have to travel more than 5 to 6km. "This wastes fuel," the executive secretary of the Changhua Fishermen's Association told a journalist about the necessity of the Changhua Fishing Port.[218] Furthermore, not just to solve the detour problem, the Changhua Fishing port was initially designed to be an essential node for developing an offshore fishery in Changhua because of its location advantage.

As fishery infrastructure, the materiality of a port shapes the surrounding fishery activities and the fishery community. As mentioned, fishers are bound to a specific fishing port depending on their boat size and fishing method, resulting in different working schedules and fishing grounds. For example, in Changhua, there are three tidal harbors, the Lunweiwan Fishing Harbor, the Wang-Gong Fishing Harbor, and the Wenzai Fishing Harbor. Most gillnet and angling fishing boats are berthed at the former two ports. Only Wenzai Fishing Harbor could offer entry and exit for large tonnage vessels, so it became the parking option for Changhua's trawling boats. The specific feature of tidal harbors restricted the coastal fisheries' working time slot between low and high tide, which left approximately 4 to 6 hours per day. Therefore, Changhua's fishing activities are primarily within 12 nautical miles, excluding cage culture in deeper waters. In short, the Changhua Fishing Port is a critical element for overcoming the tidal changes and creating new employment by splitting the southern half of the Changhua Fishing Port as the O&M base for OWE and another part for landing fishing boats (Figure 18).

In terms of material infrastructure, besides developing the multifunctional fishing port, Ørsted also planned to integrate fishing facilities with fixed WTGs in their OWF. They discussed a cooperative program with the Changhua Fishermen's Association on the feasibility of sea farming. In fact, Ørsted has been experimenting with combining seaweed farms and oyster restoration with WTGs in the North Sea. By physically integrating OWE's development into the fishery economy via fishing facilities, the OWE system co-evolved with the changing fishing economy. To materialize an OWF and utilize offshore wind, besides tailoring its social engagement programs to the needs of local politicians and fishing communities, the OWE developers would also need to make sure of a proper connection to TPC’s grid and its users.

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[218] Chuang C., "Changhua fishing port to also serve as wind farm support base?," *PTS Taiwan*, October 17 2019, https://news.pts.org.tw/article/450813.

Among the development zones established by Energy Bureau for OWE in 2015, there are 21 sites located in central Taiwan, Changhua County's territorial sea, with a total capacity of 2.4GW. These sites, including Ørsted's Great Changhua Projects, will transmit power through two common corridors at southern and northern Changhua County, respectively. Such an idea of a common corridor was brought out to lessen the impacts on marine biodiversity by gathering submarine cables from multiple OWFs (Figure 19). In turn, these power outputs will need TPC to build new switching yards and an extra-high voltage transformer station at the coast to be fed into TPC's grid. The major challenge comes to TPC's capability in creating a network that could sustain huge losses or increase power outputs within minutes from these centralized OWFs in the short term. A rapidly decreasing frequency might activate low-frequency protection of other units that led to automatic shut-off to prevent further damage to the units themselves, a brown- or black-out would follow. The issue of how to enlarge TPC's operational reserve to make the system flexible was raised again. That is, the problem did not appear suddenly because of renewables' joining, but rather was pre-existing (though escalated by the entry of renewables).

Figure 18 The schematic diagram for Changhua Fishing Port (the gray area is preserved for berthing fishing boats, and the colored area is for OWE's O&M base).

Source: Extract from the Department of Economic and Renewable Energy website, Changhua County Government, "「彰濱離岸風電運維基地」執行概況 [Implementation overview of "Changbin Offshore Wind Power Operation Base"]," 2019, https://greenenergy.chcg.gov.tw/03bulletin/bulletin03_con.asp?bull_id=304974.

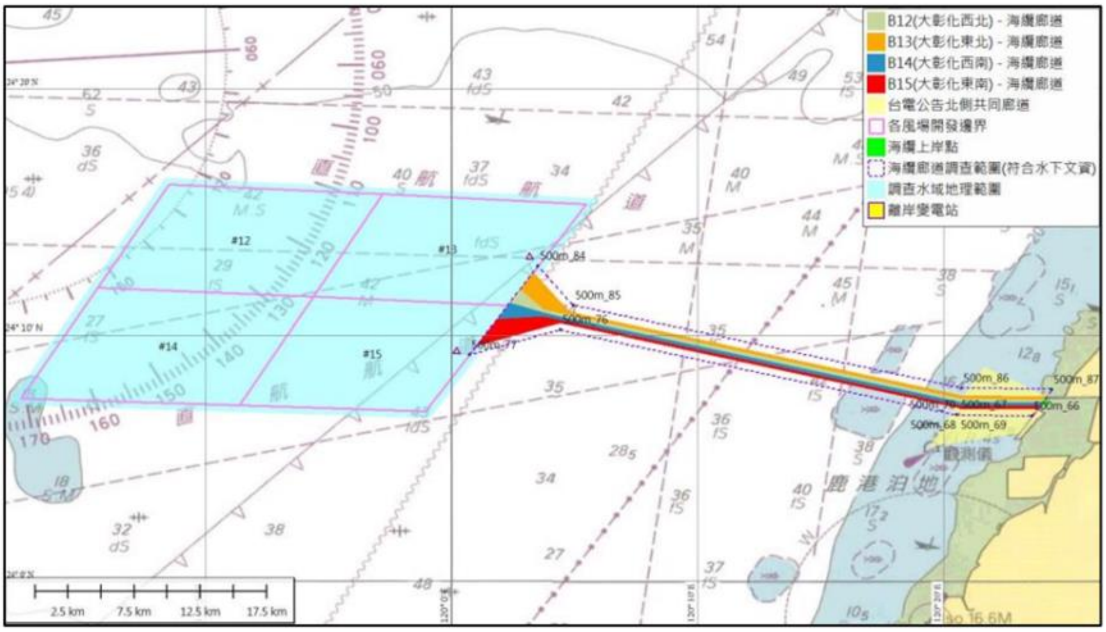

Figure 19 The northern corridor for submarine cables to interconnect Ørsted's Greater Changhua OWFs to the transformer stations in Changbin industrial zone.

B12 to 15 means the corridor for Ørsted's submarine cables, and the yellow legend indicates the corridor for TPC.

Source: Excerpted from Ørsted's slides for Vessel Information Session in 2019.

4.3.4 Brace for impacts: TPC's grid-strengthening projects

The development of OWE and other variable renewable energy forced TPC and its carbon-intensive network to rearrange themselves to reduce the risk of system malfunction. By discussing TPC's grid-strengthening projects, this section highlights another critical aspect of Taiwan's renewable transition from the perspective of grid management and system flexibility.

The second chapter explained how the locations of TPC's power plants gradually polarized in order to support the industrial power demand in the northern and southern areas of the island. During the 1970s and 1980s expansion, the completion of the Taichung thermal power plant (Chunghuo) and nuclear power plants located in central, northeast, and southeast Taiwan respectively, intensified the situation. From Figure 20, one can see a net power flow from south to north. Together with other conventional units, the extra-high-voltage transmission lines carried the power surplus from the southern parts of the system through three major nodes – Lung-chi, Chungliao, and Longtang – and then arrived at the northern load center. In other words, malfunctions or overload situations on either the nodes or lines would result in systemic failure, especially in terms of the northern region.

Meanwhile, the introduction of natural gas in the 1990s and its growing share in the energy-mix afterward required correspondent cooperation between TPC and CPC and their fuel transport and storage network. After unlading Liquefied Natural Gas (LNG) from tankers to CPC-owned terminals located at Kaohsiung and Taichung, LNG is regasified and pumped through undersea pipelines to the northern metering stations and then arrives at TPC's power plant. With hindsight, it seems that compared to the risk of LNG importation, the gas line's vulnerability is a more substantial threat to TPC. For example, an unexpected cut-off of gas supply due to maintenance work at CPC's metering station on August 15, 2017, tripped six gas turbines at TPC's Tatan power plant, which led to a sudden loss of 11.94 percent of total electricity generation and a blackout in northern Taiwan. These above factors triggered massive power outages across the island several times. Especially the two incidents that occurred in 1999 first exposed the TPC system's weakness to the public. One in July was caused by a collapse of an extra-high-voltage electrical tower leaving 82.5 percent of users in the dark.[219] Two months later, a magnitude 7.6 earthquake hit Taiwan and disrupted one of the extra-high-voltage trunk lines. Afterward, TPC accelerated the construction of another 345KV line to distribute the loads.

The scenario changes as the centralized large-scale OWE converting technologies are expected to be integrated. In TPC's blueprint, offshore wind units are planned to be integrated at 161 KV in the same position as other hydro, thermal, and nuclear plants. But on average, the capacity factor of Taiwan's land-based wind power units is around 30 percent, while offshore wind units claim 40 percent, meaning 40 percent of actual output in total installed capacity in a year. The critical issue is getting numbers from wind forecasts to regulate the power outputs from OWE systems in minutes and to schedule days-ahead in coordination with other conventional units. As a report conducted by TPC's research institute in 2011 addressed, integrating a large amount of renewable energy into the TPC system is not so much a technical issue but a problem of simultaneously raising the cost by compromising the energy efficiency and capacity factor of the existing thermal power units to cover the intermittent renewable generated power.[220] To increase the TPC system's dispatching flexibility, TPC built a meteorological mast off the coast of Changhua County in 2015 to collect data in its own OWF and also serve as a reference point to simulate the power scenarios at other nearby sites. Meanwhile, TPC has assigned its research institute to work with the Central Weather Bureau (CWB). In 2018, TPC requested further sharing of hourly meteorological data (temperatures, wind speed and direction, humidity, rainfall, etc.) and specifically CWB's numerical weather prediction by regions for refining TPC's wind forecasting model.[221]

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[219] Ji-jen Wong et al., "Study on the 729 blackout in the Taiwan power system," *International Journal of Electrical Power & Energy Systems* 29, no. 8 (2007): 589-99.

[220] Yu-yun Chou, *Operational Issues and Countermeasures for Grids with High-penetration Renewable Energy,* TaiPower Research Institute, TaiPower Research Institute (Taipei: Taipower, 2011).

[221] Wen-yen Hsieh et al., "數值天氣預報應用在風力發電預測之研究 [Study on the application of numerical weather prediction in wind power generation prediction]" (2021 Conference on Weather Analysis and Forecasting, Taipei, Taiwan, 2021); Li-fen Chou, *電力氣象地圖之規劃與系統建置完成報告 [Completion Report on the Weather Map for Utility and Energy]*, TaiPower Research Institute (TPC, 2020).

On the other hand, as power outage incidents still occur, the public pressure on the DPP's renewable transition policy is mounting. Although the causes were not because of the power shortage but because of the TPC system's weakness of low operational reserve and over-centralized network, TPC was forced to come up with a better idea instead of adding another 345 KV line. In 2022, the DPP administration approved an NTD$ 5.645 billion budgets for TPC's grid upgrading project, in which the distribution programs will cost NTD$ 4.379 billion. TPC's resilience project aims to prevent another single malfunction from causing a long-duration and massive power outage. Looking closely, TPC plans to leave the north-south 345 KV power lines to household users while building direct lines to the intensive ones. New direct lines connect existing baseload power plants and offshore wind farms to the industrial parks. For example, the future OWE-generated electricity will meet the demands of industrial parks in Taichung and Hsinchu through two 345 KV lines with TPC's coal-fired Taichung plant and gas-fired Tunghsiao plant, respectively. Accordingly, six extra-high-voltage transformer stations will be built on central Taiwan's coast to interconnect the offshore wind power and feed it into direct lines. The similarly centralized nature of OWE units could provide the intensive user's green energy demand and enable TPC to enhance regional balance in terms of power supply. For instance, Ørsted signed a corporate power procurement agreement selling 920 MW of power production from its OWFs in the Greater Changhua project on a 20 years-base to TSMC in 2020.[222]

In this sense, renewables' role within an energy transition goes beyond substitution or addition to a changing portfolio. From the case of OWE in Taiwan, one can see that the exploitation of OWE stimulates structural rearrangements and new alliances for the TPC system and the carbon-intensive network to accommodate such energy technologies. TPC’s managing strategy for the penetration of variable renewable energy is mainly about extending and improving its transmission and dispatching network. Behind the grid-enhancing program lie two major goals. One is to direct green electricity to the high-demand industrial complexes, and another is to distribute the risk of system malfunction by adding more substations in different regions to prevent the escalation from a regional power outage to a whole system failure. However, this does not suggest that the TPC system is shifting from a polarized system toward a distributed one in terms of power consumption and supply. Cities, where energy-intensive users are located, are prioritized in TPC’s grid planning. Installation of renewables, especially significant for the case of OWE, was in turn, incorporated into such a development scheme. In other words, Taiwan's energy transition exemplifies how renewable energy systems evolve within an entrenched carbon-intensive network, rather than initiating a total changeover.

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[222] Rachel Chan, "沃旭能源和台灣積體電路製造股份有限公司簽署全球最大的企業再生能源購售電契約 [Ørsted and Taiwan Semiconductor Manufacturing Co., Ltd. signed the world's largest corporate renewable energy power procurement agreement]," news release, July 8th, 2020, https://orsted.tw/zh/news/2020/07/orsted-tsmc-cppa.

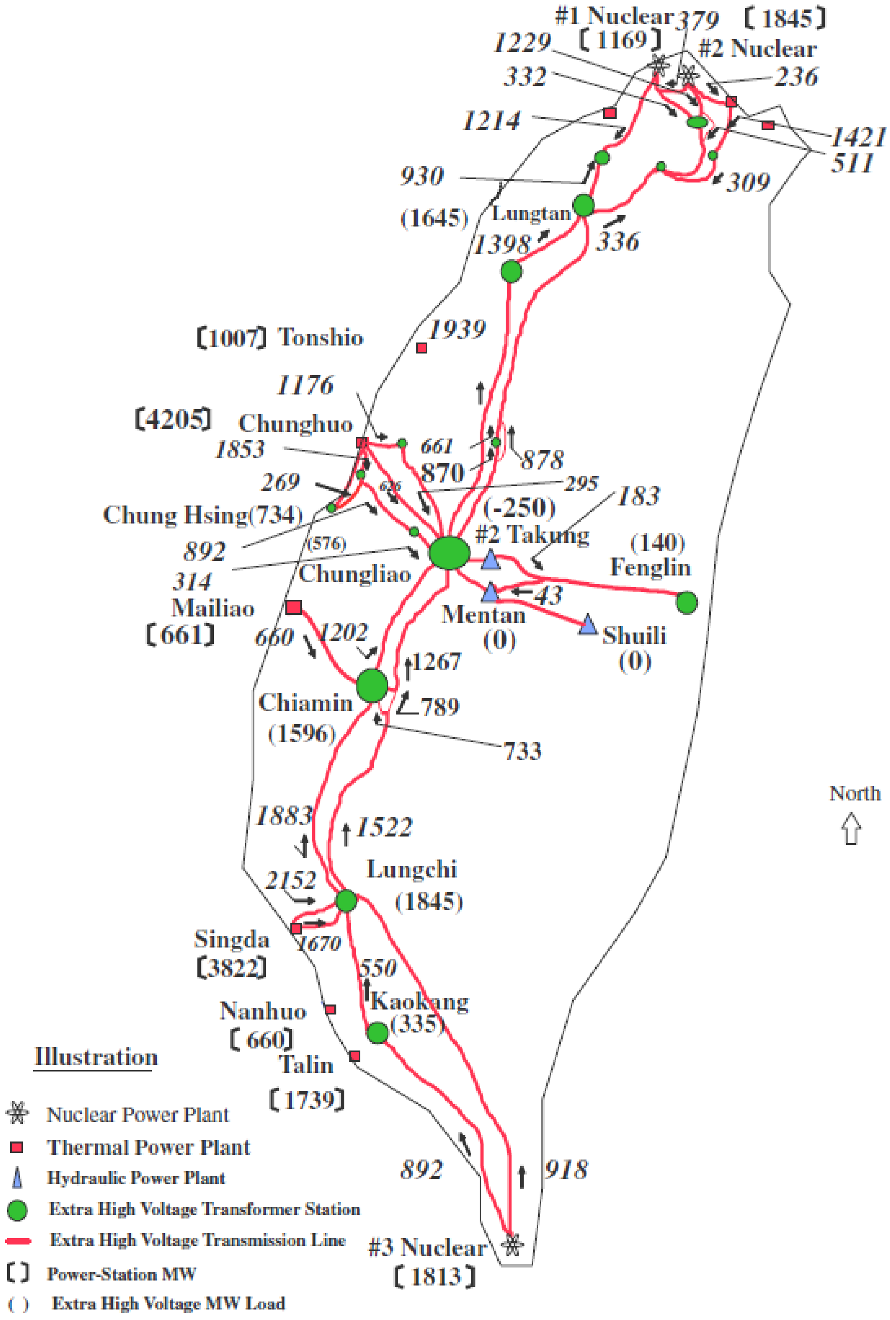

Figure 20 TPC's 345 KV transmission system by the end of the 1990s. After the blackout crisis in 1999, another north-south extra-high-voltage trunk line was accelerated and completed in 2002.

Source: Excerpted from Wong et al., 2007, Study on the 729 blackouts in the Taiwan power system, International Journal of Electrical Power & Energy Systems, 29(8), 591.

4.4 Concluding remarks

This chapter explored the incentives and factors that shaped Taiwan's renewable transition pathway. By tracing an engineer's trip from TPC's maintenance factory to the UN's first international conference on alternative energy technologies in 1961, the first section explains TPC's initial interest in harnessing wind power was to utilize it in a diesel-based power system on Penghu Island in case a declaration of emergency during wartime might leave military bases out of fuel and power. The experimental nature of wind power projects and limited resources for dealing with maintenance issues did not make it a feasible option for TPC. Until 1980, ITRI's energy lab's establishment brought R&D investments and talent into the field of wind and solar power conversion technologies. ITRI’s focus at the time on small wind systems also suggested a very different path and vision for wind power development on Formosa Island compared to the 2010s. As the TPC system continued to expand in terms of its baseload power plants and fuel network in the 1980s, renewable energy units stayed at the margin. But facing the social upheavals flowing from TPC's expansion agenda, TPC found help from the co-generation units and facilitated Taiwan's first electricity market deregulation to promote their installation. The carbon-intensive users were the targeted actors to become the IPPs with such distributed generation units. In turn, the TPC system sustained its inertia to expand by strengthening its ties with these IPPs through the 1990s. On the other hand, deregulation also paved the way for the future integration of decentralized renewable units and renewable developers who became the lobbyists in helping to pass DPP's bill of renewable transition in the 2000s.

Taiwan's political climate experienced a major change as DPP won the presidential election for the first time in Taiwan's history in 2000. As its administration committed to turning the island county into a nuclear-free homeland, the second section explains how renewable energy's development became closely tied to the controversial nuclear units, especially after the Fukushima Incident. The 2017 amendment of the Electricity Act symbolized the starting point for Taiwan's energy transition by demanding a substantial transformation in terms of market design, regulation, and TPC itself. However, the setbacks from the 2018 referendums' pro-nuclear result suggest the importance of stable policy support to keep up the pace of the transition. Outside the parliament, to understand what enlarging renewable electricity to 20 percent of the total generation in Taiwan entails for the local society and the existing carbon-intensive network, the final section examines the sociotechnical impacts brought about by onshore and offshore wind projects. With the cases on Penghu Island, which has been treated as the test site for wind power and later a prominent low-carbon future by the Government, the result of the deserted wind projects indicates that in Taiwan, the benefits accompanying the wind-generated electricity flow seems to have more substantial influence at the local level – but so do the conflicts. Furthermore, the TPC system's failed attempt to bring Penghu Island's power network into its system in time due to the local protest over the submarine cables’ construction also hints at how the TPC system's growth within Taiwan's renewable transition would encounter another level of conflicting interests.

The controversies revolving around the larger-scale wind turbines erected on the seabed due to the overlapping areas with fishing activities and marine mammals' habitats further brought the long-standing ecological, economic, political, and social tensions over Taiwan's green energy-oriented policy to the surface. In the massive area that Taiwan set aside for OWE concessions, OWE development in Changhua County provoked conflicts that arose from multiple aspects and across governmental levels. By supporting Tsai's policy, the incumbent administration of the Changhua County Government expected to attract foreign investments and funds from the central Government to improve critical infrastructures, such as fishery ports and roads, and in turn, to gain public support for the next term. Meanwhile, the local fishermen staged numerous protests against the offshore wind farms for eclipsing their operation area, in line with environmental NGOs' objection to its possible damage to marine ecology. These differing positions and the ensuing controversies indicate that renewable energy infrastructure, as the material foundation for Taiwan's energy transition, challenges the priority of nuclear energy and the extant power relationships at sea and within society. Finally, the multitude of challenges and system breakdowns forced TPC to rearrange its power network to fix the long-lingering problems of its low operational reserve. To prepare for extensive wind penetration, TPC began developing its wind forecasting technologies to increase dispatch capability. Meanwhile, the characteristic of OWE is utilized in TPC's grid upgrading plan to assure the carbon-intensive users of a source of green energy and a stable power supply.

Following wind turbines from the offshore islands to the shore and the sea, this chapter discusses Taiwan's two decades of efforts in renewable transitions and the sociotechnical implications between the contested scenes. It also exhibits how the incumbent carbon-intensive infrasystems integrated new energy technologies of different types of wind systems under various expectations of certain energy futures over time. Such system adaptation explains why Taiwan’s current renewable transition means the continuity of the carbon economy through revealing the fixated operating logic of the infrasystems and energy politics. It also leaves us some clues for the direction of Taiwan’s energy future, especially considering the increasing importance of natural gas in the decarbonization scenarios with or without nuclear power.

Chapter 5: Understanding today through Taiwan's energy past

Figure 21 After the EPA approved the CPC's third LNG terminal's EIA report, the demonstration was held at the coastline of the Datan Borough.

Source: Excerpted from Andrew Silver, "Taiwanese scientists fight construction of a new port they say would damage a unique reef," Science (November 21 2018), https://www.science.org/content/article/taiwanese-scientists-fight-construction-new-port-they-say-would-damage-unique-reef.

Crucified effigies representing the Taiwanese humpback dolphin and the *Polycyathus chaishanensis* coral were displayed along with protestants forming a human chain at the Datan Borough in November 2018. This protest expressed an outcry over the government's approval to construct CPC's third LNG receiving terminal, whose location overlapped with the endangered species' habitats. Nevertheless, despite facing severe protests, CPC managed to push through the construction plan in the following years. In 2020, this issue became again a prominent public issue as a proposal for Taiwan's 2021 referendum. During the referendum, the protestors against CPC's gas facilities would frame their series of actions as protecting the algal reef from ecological degradation; but in favour of the government's renewable transition, which aimed to increase electricity generation from LNG to 50 percent by 2050. Such a framing strategy further shows the present-day dilemma of Taiwan's renewable transition: the co-evolution of renewable energy technologies and the entrenched carbon-intensive network, including its fuel infrastructure.

So far, my dissertation has argued that such an event should be seen as a collective reaction to Taiwan's carbon economy. As I will show in section 5.1, the reasons behind the controversial Datan Borough show how Taiwan's struggles with its current setbacks of renewable transition have, in fact, resulted from its long-existing carbon-intensive infrasystems. While monitoring the process of adaptations when introducing new energy technologies into the systems, my historical study attempts to offer some insights based on the physical limitations of extant infrastructure, TPC's operating patterns, and the materialities of energy carriers from a long-range perspective. In this concluding chapter, the Datang algal reef controversy is another case in point for my interpretation.

This conclusion will start with a discussion of the debate over the construction of CPC's third LNG terminal. By exploring the case, the aim is to summarize this dissertation by placing my two research foci within the algal reef story and thereby to make sense of today's controversies: those foci being the *multiplicity* of energy pasts and the *obduracy* of carbon-intensive networks.[223] How was the landscape of Datan Borough rescaled under different energy visions and reshaped from an industrial zone to an indispensable point of Taiwan's LNG network? The ecological concerns with the growing dependency on LNG does not only happen in Taiwan but also in other attempts to energy transition elsewhere under the "carbon neutral" frameworks. The discussion could also contribute to the transition studies literature by providing an understanding of the involvement of LNG in increasing the path dependence and lock-in effects of carbon economies. In Taiwan, the allocation of natural gas in the TPC system began in the 1990s and gradually replaced fuel oil and coal as Taiwan's primary power source. The relatively low carbon emission of electricity generated by LNG played an even more prominent role in today's decarbonization vision.

On the other hand, it also shows how energy issues are intrinsically political since they become the vehicle for carrying out different national goals and manifesting the competition for power and resources among political parties, local and central government, social groups, and non-human actors.[224] The algal reef did not suddenly appear in this case but had been there for 4,000 years, at least on Taiwan's northwest coast. Politicians or interested groups spoke out and represented their survival rights, which often directed the discussions toward the competition between ecologically driven values versus development-driven (or growth-driven) scenarios. However, as I will argue later in section 5.1, the tension stemmed from the past ways of distributing risks and benefits that had (re)shaped the power relations between

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[223] The concept of the multiplicity of energy pasts highlights the fact that our perspective on the ideal energy mix or certain energy source differs depending on the situation. The Datan algal reef case is a prime example of this. It is not only a matter of renewable energy transition plans but is also a consequence of TPC's decision to invite Independent Power Producers (IPPs) to construct an LNG-fired power plant in the Guantang industrial zone in the 1990s. This decision was a response to the public's concerns about the environmental hazards of coal- and oil-fired plants. Moreover, the construction of the LNG-fired power plant was also justified by the need to expand the petrochemical industry, which was the main purpose of the Guantang industrial zone. Therefore, although both renewable energy transition plans and market deregulation in the 1990s resulted in a rising reliance on LNG, they represented different energy visions. By clarifying these past visions, we can better comprehend the challenges in finding alternative solutions in this case.

[224] Here is an extension of Hecht's concept of technopolitics. As Hecht explained, it is "the practice of using them in political process and/or toward political aims constitutes technopolitics." See Hecht, *The Radiance of France: Nuclear Power and National Identity After World War II*, 15.

urban- and remote areas, between powerful and vulnerable groups, and between human- and nonhuman actors. The power struggles among the heterogeneous array of stakeholders involved could also be seen in cases of blocking the installation of nuclear power units or wind turbines in Taiwan. Those conflicts arise not because they are "politicized," contaminated with misleading information, or poorly communicated. Instead, the site selections and the corresponding risk distributions and management strategies result from TPC's development logic, the technical problem of grid interconnection, and past energy decisions. These disputes also reflect the consequent exploitation of remote regions and relatively vulnerable groups that exacerbated Taiwan's uneven regional development from a long-range perspective.

5.1 The Algal Reef Puzzle

To avoid being caught up in more controversies in the 1980s, TPC urged the government to deregulate the electricity market and allow energy-intensive users to independently generate electricity from cogeneration units. Meanwhile, to de-escalate the tension of potential protests, TPC formulated a "Neighbouring Work Projects" scheme for calculating the amount of compensation and the shares of feedback funds, and for drawing the boundary of the recompensed area to avoid endless negotiations. In so doing, the developmental risks and potential environmental hazards became manageable under such schemes. Such a strategy of containment was not only applied by TPC but also by other carbon-intensive users, such as Formosa Plastics.[225] As the carbon-intensive infrasystems endured and expanded its scope by coordinating partners across multiple industries, the countervailing forces consequently became more diverse, entrenched, and entangled with local political issues in the following decades. The algal reef versus the construction of CPC's third LNG receiving terminal resided in the Guantang industrial zone is a case in point.

First and foremost, the purpose of setting up the Guantang industrial zone is to deliver LNG to TPC's Datan power plant. They were both planned in 1996 and when the original investor of the Guantang industrial zone, Dong-ding Liquified Gas Corporation (CPC took over the project in 2016), conducted its first EIA report in 1997, the term "algal reef" was not even mentioned.[226] Furthermore, in addition to the planned LNG/LPG terminals, the zone also included terminals for transhipping petroleum products, crude oil, and cement. Here, we once again see the further expansion of the carbon-intensive infrasystems in the 1990s. In order to support the industrial growth of the intensive users since the late 1980s, Taiwan's port system, in a sense, diversified with the carbon-intensive network as well. Exclusive industrial ports like

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[225] See Jobin, "Our 'good neighbor'Formosa plastics: Petrochemical damage (s) and the meanings of money."

[226] *桃園縣觀塘工業區（含工業專用港）開發計畫環境影響說明書 [Environmental Impact Statement of the Development Plan of the Guantang Industrial Zone (including the Industrial Port) in Taoyuan County]*, (Dong-ding Liquified Gas Corporation, 1997), https://eiadoc.epa.gov.tw/eiaweb/10.aspx?hcode=0860621A&srctype=0.

Guantang emerged in the 1990s to support the corporations' berthing and loading/unloading needs in Taiwan's industrial parks.[227] As I will proceed to point out, though, what endangered the algal reef habitat was not only particular, new energy infrastructures but also the obduracy of the carbon-intensive infrasystems.[228]

In principle, the natural coastal sand drifting will temporarily cover the reefs, but with the movement of the intertidal dunes, the reefs will still be exposed and continue to serve as the habitat of fish, crabs, and macroinvertebrates. In other words, the drifting sand brought by sea waves helps to keep a dynamic balance and a rich ecological system at the coast. The construction of the breakwaters for the industrial zone would disturb the drifting sand. Yet, according to the initial masterplan of the Guantang industrial zone, it would not only change the coastline but also be built on the reefs directly, thus stirring up as much mud as doubts at the local scale.

After the Environmental Protection Administration granted the green light to Dong-ding's EIA report in 2000, CPC installed the LNG pipelines to the site in 2007 and triggered the first wave of the algal reef preservation movement – a campaign for the setup of the Guanxin Algal Reef Ecosystem Refuge — attempting to overturn the decision. The campaign for protecting the algal reef habitat reached its apex in the national referendum in December 2021, in which voters were asked to answer yes or no to the question, "Do you agree that CPC's LNG terminal should be relocated from its planned site on the algal reef coast of Datan and its adjacent waters?" Such a full-stop approach was a countermove in response to the DPP administration's prompt reply to the protests against the exclusive LNG terminal in May with a revised version of the construction plan to push the jetty further off the coast by 1.2 km and minimize the developing area to only 10 percent of the initial plan. However, the leading opposition group, the Algal Reef Reservation Alliance, did not accept such a compromise. Meanwhile, they also did not expect the subsequent unprecedented opposition to the preservation campaign due to LNG's essential role in the DPP's scenario of a gradual renewable transition without nuclear power, especially considering that the third LNG terminal will be commenced by 2025.

In retrospect, the case suggests further scaling up (and appropriating) the narrative and mobilization strategies deployed in the anti-Su-ao thermal power movement. In 2018, CPC sent the modified EIA report for the port construction, which the Environmental Protection Administration (EPA) originally approved in 2000, to the EIA committee. The proposal was

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[227] See Bing-yan Lu, "我國工業專用港轉型改制為工商綜合港之公共政策觀點-政策網絡與政策變遷的應用," [Taiwan's industrial ports transformation policy: an application of policy networks and policy change theory.] *Taiwanese journal of Political Sciences*, no. 19 (2003): 255-96.

[228] The concept of obduracy refers to the endurance of certain developmental or operational patterns and power relationships resides within a social or concrete space like urban area or specific transportation systems. See Anique Hommels, "Studying obduracy in the city: Toward a productive fusion between technology studies and urban studies," *Science, Technology, & Human Values* 30, no. 3 (2005): 323-51; Anique Hommels, *Unbuilding Cities: Obduracy in Urban Sociotechnical Change* (Mit Press, 2008), 292.

rejected in July but was eventually granted the green light three months later. In response, a group of supporters, including a reef biologist affiliated with Academia Sinica and a marine biologist from Tunhhai University, organized a demonstration in November, setting in motion the protection movement (as shown in Figure 21). We can see how the coalition of environmental NGOs and scholars tried to displace the successful strategy from 2011 of petitioning to protect the Taiwanese humpback dolphin's habitat against constructing the Kuokuang Petrochemical complex. Nevertheless, their objections to the new national project suggested tensions arising from the subtle changes in the Alliance between the DPP and environmental organizations, this time due to the DPP's broader framework of a Nuclear-Free Homeland by 2025.

The background of the Algal Reef Reservation Alliance convener, Pan Chong-cheng, hints at the tension in Taiwan's energy politics after the 1980s. As a resident of the Guanyin district in Taoyuan since 1983, he devoted himself to the pro-democratization movements and joined DPP with a particular interest in the local environmental protection movement. Pan's political career resembles that of many early DPP members. During the KMT-led cabinet running the government from 2008 to 2016, Pan utilized his connection with the DPP and pushed through implementing the Guanxin Algal Reef Ecosystem Wildlife Refuge in July 2014, adjacent to the Datan power plant and algal reef habitat. However, the ensuing LNG terminal controversies since 2018 forced Pan to oppose the DPP. In fact, the 2021 Cherish Algal Reefs Referendum further shows the political fragmentations within the formal DPP coalition.

Although the environmental NGOs favoured DPP's policy of renewable transition, the seemingly inevitable continuity and even growing dependency on fossil fuels had led to further divisions in visioning the "sustainable energy futures." Accordingly, new alliances emerged between the disappointed advocators and other political parties, such as the Green Party Taiwan and the New Power Party. This further shows how Taiwan's energy issues are getting much more entangled with local politics compared to the late 1980s. Facing the unexpected backfire of the campaign, the Algal Reef Reservation Alliance shifted its focus from criticizing the ecological impacts to possible alternatives for relocating plans for the LNG facilities in response to the many accusations of stalling Taiwan's decarbonization plan. The proposed alternatives included Taipei Port, Linko Port, and the expansion of the existing two LNG receiving terminals. However, the structural limits of the industrial port systems made these alternatives unlikely to be materialized.

Taiwan has three exclusive industrial ports, including the still under-construction Guantang Port. The Mailiao port was first drafted in the context of the continuously rejected Formosa Plastics' sixth Naphtha cracking plant in 1989 and was approved by the Executive Yuan in 1993 for unloading imported crudes and coal and exporting products from/to the Formosa Plastics petrochemical complex and the Mailiao Cogeneration Corporation in Yunlin. Another already-built exclusive industrial port is the Hoping Port. Its birth was in accordance with the Taiwanese government's policy of moving the cement industry to eastern Taiwan in the late 1980s. The Hoping port bears the mission of transporting coal for TPC's Hoping power plant at the port and transhipping limestone, cement materials, and products from/to the Taiwan Cement Corporation's factories in Yilan and Hualian and the nearby industrial zones. Finally, the disputed Guantang port was intrinsically a project including the construction of an LNG terminal, gasifying station, and storage facilities at the waterfront industrial zone in Taoyuan designed explicitly for the operation of TPC's Datan power plant since 2000. In short, one can see how the hard-to-break linkages of the infrasystems, industries, and the power structures behind became fixed in place since the late 1980s and shaped Taiwan's current renewable transition.

For instance, the Alliance proposed that by expanding the Taipei Port, TPC should be able to get sufficient LNG for its adjacent Datan and Xiehe power plants in Keelung; while before its construction, they assumed that the demand for the Datan Power Plant could be supported by expanding the existing CPC's first and second terminals at Yongan and Taichung. However, Taipei Port is a commercial port requiring a series of arrangements to accommodate bulky LNG carriers. The Ministry of Economic Affairs further stressed that the required land reclamation would take 11 years to complete; meanwhile, in order to transport LNG to the Datan station, another 50 kilometers of the submarine pipeline would need to be installed across five algal reef areas, which would bring about even more severe damages. Compared to the Taipei port, Linko port is TPC's coal terminal situated much closer to the Datan station, which could utilize the already laid pipeline interconnecting with the IPP-owned and LNG-fueled Ever Power station. Utilizing the existing infrasystems proved less feasible because the port is located directly under the aircraft flight path and needs to undergo flight safety examination again for further expansion plans. Lastly, CPC pointed out that the current utilization rate of the Taichung and Yongan receiving stations has already reached 115 percent, and the pipelines also required further extension by 2027. Therefore, the network would not be able to meet the forecasted demand in 2025.[229] From an integrated systems perspective, the obduracy of the industrial port systems made the Guantang port the indispensable point of Taiwan's LNG network.

At the end of the 2021 referendum, the proposal did not gain sufficient support to reach the passing threshold, which suggests the DPP administration's reiteration of possible power shortages in conjunction with the CPC's adjusted version and the corresponding compensation measures had succeeded. CPC's alleviating measures targeted the major concerns and interests during the debates. For example, CPC set up a 24-hour real-time camera to make the controversial Datan algal reef areas visible to the public during construction and plans to establish an environmental trust to initiate public-private cooperation on local ecological

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[229] . CPC, *第三座液化天然氣接受站可行性研究 [Feasibility Study on the Third LNG Receiving Terminal]* (2014), https://www.cpc.com.tw/cl.aspx?n=3481.

preservation activities, which has been one of the significant targets of the Taiwan Environmental Information Association since its establishment in 2000.

Exploring the algal reef puzzle through the lens of the carbon-intensive infrasystems helps to rethink the issue, not simply focusing on the relationship between the survival of the algal reef versus the construction of an LNG terminal. Instead, underlying the debates were the structural limits of Taiwan's carbon-intensive infrasystems and the dynamics of the political coalitions among major parties in forging the consensus of Taiwan's ideal energy future. In other words, what complicates the issue is Taiwan’s energy politics and the structural effect of infrasystems. As this dissertation has argue, to understand the conflicts between various visions of the energy future, it is essential to situate them with respect to the energy past. From early post-war Taiwan’s devastation and urgent need for infrastructuring its industrial sector and political regime to the contemporary re-infrastructuring demand coinciding with the ecological degradation in the algal reef dilemma, I will proceed to elaborate on how the previous empirical findings could be summarized under the two research themes in the following section.

5.2 Two major research themes

The previous chapters revisited Taiwan's changing energy mix of its power system from a long-range perspective. Examining TPC's past energy decisions closely, I intended to make sense of their engineers' conceptions of an "optimal energy mix" over time under specific circumstances. Moreover, in order to understand the relationship between Taiwan's energy politics and its carbon economy, my study presents a dynamic picture of the decision-making process involving various actors. As the story unfolded, this dissertation found the often-overlooked role of the TPC engineers was critical in managing Taiwan's power supply and driving industrial development over time. They engaged intensively with transnational consultants, bureaucrats, industrialists, coal miners, fishers, scientists, and protestors, as well as collective actors such as NGOs and renewable energy companies, and nonhuman actors such as dolphins and migrating birds to manage stable power output amid the uncertainties of different energy carriers.

From the domestic coal problem to the geopolitically and socially contested issues of deploying fuel oil and nuclear power, natural gas, and harnessing renewables, tracing the course of Taiwan's past energy futures helps to clarify at least two major changes needed to the current historiographical image. First, it becomes clear that an optimal energy structure was not simply based on the cost-benefit ratio of certain energy sources. To manage the different materialities of hydropower, steam coals, diesel, fuel oil, natural gas, nuclear, wind, and solar, TPC would require corresponding support from various actors such as government agencies, energy companies, industrial users, and other infrastructure. Yet, the state's leading role – whether in the form of crisis reactions to the skyrocketing oil price, international nuclear disasters, the growing environmental awareness, or the global pursuit of decarbonization – has been over-stressed in prior works. The state's influence of policy instruments overshadows the actual practices of transnational, cross-industrial sectors, or cooperation between governmental agencies in dealing with the challenges of its carbon-intensive systems. Especially considering Taiwan's distinct geopolitical position, it can be characterized as a global island shaped by its colonial past and evolving international political situation. That historical context has contributed to its growing independent and strategic agency in dealing with geopolitical stresses while significantly relying on a global network built on bi- and multilateral transnational assistance programs and trades. This dissertation finds such traits essential in unpacking the complexity of Taiwan's past and current energy issues. Therefore, I argue that solely taking the state's reactions toward specific crises into account cannot fully explain the turning points of Taiwan's energy structure nor the structural limits constraining its renewable transition.

Second, the previous chapters have shown how the energy transition of a power system means aggregated and layering efforts over decades and across sectors, which in turn, makes a more radical transition difficult.[230] Studying the historical process helps to indicate how a society undergoes a series of institutional, technological, and social innovations to adapt to the changes in its carbon economy and energy structure. In other words, these adaptations also suggest how society consumes and exploits energy through systemic coordination among electricity grids, railways, ports, oil and gas pipelines, and energy storage facilities. Not only the ideas and agencies of the historical actors will lead to certain energy choices, but also the energy configuration and supporting infrastructure will impose physical and structural limits on the decisions. Therefore, this dissertation proposed to analyze the almost 80-year development of Taiwan's electricity system from two major aspects: the multiple energy futures in retrospect and the obduracy of the carbon-intensive infrasystems.

5.2.1 Multiple energy futures in retrospect and tensions between them

In order to contextualize energy transitions, it is essential to recognize the system dynamics that are driving their materialization and to view them not as a result of consensus but as plural processes within which tensions reside. Reviewing Taiwan's transition from a hydro- to a thermal-power-based system, it is clear that the preparatory work for such a shift had already been set in motion in the 1950s. Chapter 2 observes how TPC engineers with different training backgrounds proposed their approaches to stretch the TPC system network to the polarized load centers. It specifically discusses the shelved vision from the hydraulic

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[230] Scholars also use the term of “palimpsest” to describe the repetitive efforts in reshaping the infrastructural transformations in historical geography and architectural studies. See for example, Christina Schwenkel, "Socialist palimpsests in urban Vietnam," *ABE Journal: Architecture Beyond Europe*, no. 6 (2014): 1-19; Mike Crang, "Envisioning urban histories: Bristol as palimpsest, postcards, and snapshots," *Environment and Planning A: Economy and Space* 28, no. 3 (1996): 429-52.

engineer Chu Shu-Lin's blueprint in 1952, pinning hydropower plants at rivers across the island, and the appropriation of the TVA model in the Da-Jia River development plans in the late 1950s. Readers can sense a shift that suggests TPC's system planning focus of a single power plant was replaced by the coordination between different energy carriers from a systemic approach. The widespread enthusiasm toward the commercialization of nuclear reactors and the multi-functional dams in East Asia had forged a different perception of the energy future that fit well with Taiwan's contemporary industrial structure and power system. That is, installing thermal power units at the Nanpu power plant to support its southern industrial port city while expecting the interconnections of new power generators, such as pumped-storage hydropower plants and nuclear units, into the TPC system.

Nevertheless, the uncertainty of domestic coal proved to be not so much about the geographical reserves but their accessibility under the government's market liberalization policy. TPC engineers in the fuel department went through enormous troubles dealing with the contracting, transportation, and poor quality of domestic coal in negotiations with other government agencies until importing fuel oil became economically feasible with the Kaohsiung port's concurrent extension programs in the 1960s. By utilizing TPC's in-house journal articles, I was able to grasp the subtle changes in the system builders' mindsets. Furthermore, studying the tensions within helps to indicate how the momentum toward transition was building up from a constellation of opinions within TPC and their interactions with the state agents.

While Chapter 2 addresses the visions and struggles in deploying coal or oil in substituting hydro as Taiwan's baseload power source, Chapter 3 describes the mounting tensions within Taiwan's society over system builders' blueprints at the beginning of the 1970s. It is a crucial era to support my emphasis on understanding the transition moments by tracing the various conceptions of ideal energy futures held by different interest groups. As Taiwan's international influence was at stake due to diplomatic setbacks, TPC was granted more agency to diversify its mining and shipping business investments to acquire foreign coal and uranium to handle the geopolitical uncertainty and sustain the carbon-intensive network. In turn, the growing sizes and numbers of fuel storage and transportation systems made their externalities palpable to the public.

In the ensuing decade, Taiwan's energy politics converged with the nation's democratization. TPC's reactions against multifaced challenges in the 1980s deepened the divergent public attitudes toward the nuclear issue and political polarization in the form of KMT and non-KMT factions. Here, the failed transition from coal- and fuel-oil-based power systems to nuclear-based in the 1980s was appropriated by a different set of actors that challenged the planning authority of TPC and the KMT government. For instance, at the end of the anti-Su-ao movement, the Yilan city government worked with the NGOs and successfully established Taiwan's first migratory bird sanctuary, overlapping with TPC's proposed site for the Su-ao thermal power plant, which became the last straw. Later on, Taiwan's energy politics became further entangled with local politics and the idea of ecological preservation.

Chapter 4 highlights the tension between political parties, central and local governments, developers and social groups, and human and nonhuman relationships in Taiwan's pursuit of phasing out nuclear power and the growing attention to harnessing renewable energy at the turn of the 2000s. First, it explains the various reasons behind TPC's earlier efforts in experimenting with wind turbines on Penghu Island in the 1960s. In the initial stage, the distributed onshore wind turbines on Penghu or adjacent to factories were not connected to the grid and thus remained marginal to the TPC system and the local society.

With the size of wind turbines scaling up along with the technical advance of the direct-drive turbine design, whether to interconnect with the TPC grid was extremely important for attracting investment and local politicians' interest. In other words, as the proliferation of distributed generators increased under the DPP's renewable transition policy and a broader nuclear-free homeland scenario, Taiwan's energy politics became extrinsically intertwined with the fragmented and complicated local politics as well. Moreover, the discussion about the contested offshore wind farms in Changhua County showed how different actors managed and debated each other over the invisible offshore wind capacity, fish stocks, and political interests. Here, another aspect of tension rising from the significant penetration of offshore wind power into the mature TPC system needs to be addressed to understand the systemic impacts of Taiwan's current renewable transition, which I will further elaborate on in the research theme of the infrasystems perspective.

In short, instead of delineating Taiwan's history of energy transitions through static statistics on changing energy portfolios or the ebb and flow of energy policies, I propose to understand those critical moments of the systemic changes by studying how historical agents crafted the contested energy futures and shaped their practices in specific historical contexts. This dissertation especially underlines TPC engineers' role in handling tensions surrounding the exploitation of hydrocarbon fuels and the configuration of sociotechnical systems. Along the way, the TPC system gradually stretched itself across the island and the global network to establish and sustain a constant growth of its carbon-intensive network and industrial users. The following research theme I will now discuss is how to capture the characteristics of such momentum.

5.2.2 Understanding carbon-intensive infrasystems

Contextualizing the various visions that directed energy practices helps explain why certain energy futures were much more ideal to engineers, policymakers, industrialists, and communities than others. Meanwhile, to understand the practices of mobilizing resources to facilitate the transition and maintain the inertia to sustain potential challenges, an integrative systems approach is needed to explain the momentum. This dissertation elaborates on such a system synthesis by examining Taiwan's carbon-intensive network consisting of TPC's transmission and distribution lines, substations, different power units, electrical manufacturers, regulating authorities, and the corresponding fuel network and transportation systems. My analysis particularly focuses on delineating the growing interdependency among hydrocarbon-dependent infrasystems. In turn, the infrasystems approach allows this dissertation to trace the historical foundation of Taiwan's carbon-intensive network.

Chapter 2 details how TPC turned from domestic coal to imported fuel oil in the late 1960s, especially by installing oil-fired units at the Talin thermal power plant near the newly dredged second entrance of the Kaohsiung port, which signaled the beginning of Taiwan's carbon-intensive infrasystems. To TPC's system, deploying fuel oil meant replacing the fuel source from the Coal Administration with CPC, the fuel transportation system from railways to waterways and through pipelines, and the economic geography from supporting an agglomeration of chemical and light industries to planned petrochemical and heavy industrial complexes.

From 1963 to 1969, the natural gas deposit was successfully extracted in the island's Northwest and further allocated for electricity generation. Harnessing domestic oil and natural gas had brought hope to the TPC's fourth power development plan (1965-1969). Furthermore, a nuclear power plant was written into the TPC's agenda for the first time in 1964. The subsequent installation of large-capacity thermal power plants, fast-start-up gas turbines, and diesel-fueled power generators for auxiliary electricity generation hinted at the scaling up of system synthesis and interdependency between TPC and CPC networks. In 1968, Taiwan's first comprehensive energy policy, the optimistic forecast toward such an energy future, along with Taiwan's growing dependence on imported energy, was built on the continued expansion of the corresponding carbon-intensive networks. In other words, systemic interdependency means the development of the TPC system would inevitably involve the configuration of transport systems and industrial activities.

Despite the challenges posed by dependence on fossil fuels, TPC and the policymakers overseeing it made every endeavor to enhance the endurance of the carbon-intensive networks. These efforts could be seen in the co-evolution of the infrasystems, including coal yards, oil tanks, exclusive terminals, pipelines, and transshipping ports needed to sustain the expansion momentum of the TPC system in Chapter 3. Since the 1970s, there has been a proliferation of supportive infrasystems and an extension of their linkages across the island. Here, we see the growing "systemness" of the TPC network and the infrasystems that support my argument that developing nuclear power was a result of TPC's low operating reserves and the precarity of carbon-intensive networks and was therefore intended as a life preserver for those networks rather than as a turn away from them.[231] However, the ensuing expanding

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[231] Gunilla Jönson, Emin Tengström, and Arne Kaijser, "How to Describe Large Technical Systems and Their Changes over Time?," in *Urban Transport Development* (Springer, 2005), 12-19.

logic of the carbon-intensive network also resulted in its significant vulnerability of low flexibility in terms of operating reserves. The second energy crisis in 1979 and the ensuing economic recession caused the decline from the demand side and changed the major governing issue from fuel scarcity to over-capacity.

Furthermore, the extending network along with its emitted pollution provoked large-scale protests in the 1980s. As Arne Kaijser observes, "a growing interwovenness of infrasystems will also lead to an increasing complexity and vulnerability. A breakdown in one system may get almost instant repercussions in many other systems."[232] In turn, the two energy crises in the 1970s proved less harmful to the incumbent infrasystems than the escalating public disputes against the increasing nodes of the carbon-intensive networks. As the anti-Su-ao movement coincided with the controversial fourth nuclear power plant in Chapter 3, the subsequent termination of the fourth nuclear power plant and the market deregulations in the following decades substantially impacted Taiwan's transition pathway.

In Chapter 4, I follow the TPC's first steps toward an actual low-carbon transition and the sociotechnical implications of those steps, emphasizing the infrasystems' structural limits and persistence. The TPC's failing attempt to expand Penghu Island's on-shore wind power programs since the 1960s supports what Allan Dahl Andersen has identified as the often-overlooked element in energy transition studies, the transmission infrastructure, referred to as "infrastructure blindness."[233] In line with this argument, an integrative infrasystems approach allows my study to show that the fate of OWE development in Taiwan lies in the developers' strategies in linking up various stakeholders' interests via transforming port facilities (the O&M port and fishing ports) and the incumbent TPC system. The offshore wind turbines provide TPC systems with large-scale and concentrated renewable power sources while also posing challenges to their grid capacity. TPC's subsequent grid improvement programs, which directed OWE-generated green electricity to industrial complexes, suggest that the corporation's primary transition target is carbon-intensive power users. That strategy allows TPC to replace a certain amount of consumption with green energy while maintaining the continuity of power-consuming behaviors and energy exploitation patterns.

5.3 Future research directions

Before I turn to reflective thinking on the aftermath of Taiwan's carbon-intensive networks, I would like to address some contributions of this dissertation and the possible research direction for future studies. First, my dissertation indicated that Taiwan's energy transitions turn out to be slow processes of incremental efforts and system adaptation. Instead of the scarcity issue of domestic coal because of the geographical limitation as an island

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[232] Kaijser, "Redirecting Infrasystems towards Sustainability," 176.

[233] Allan Dahl Andersen, "No transition without transmission: HVDC electricity infrastructure as an enabler for renewable energy?," *Environmental Innovation and Societal Transitions* 13 (2014): 75-95.

country, this dissertation argues that what gradually changed the TPC engineers' minds with the introduction of imported fuels to its energy-mix was the difficult quality and transport management of domestic coal, the emerging hydrocarbon-based industry, and the extending of Kaohsiung port in the 1960s. That is, the materiality of energy carriers and the causal interactions of the infrasystems, which interconnected the nearby industrial power users, generated the momentum of the growing carbon-intensive network in the 1950s-60s. If researchers only consider Taiwan's current dependency on imported energy as the result of the "carbon economy" or dated such a tendency only from the 1968 energy policy as a "breaching point," these claims could be easily overturned as the path dependency had already taken shape in the 1950s. Without pointing at critical events or structuring niche, regime, and landscape categories, this dissertation illustrates the formation of such infrasystems by following historical actors' back-and-forth discussions on certain energy carriers/technologies and making sense of their choices through their various solutions and visions.

This point is perhaps valuable for transitions studies and MLP studies in general. When studying the present-day renewable transitions, it is necessary to historicize the energy decisions and visions while considering the co-evolution of the supportive infrastructural systems and industrial structure that help the incumbent energy system adapt to the possible changes. Especially in critical moments such as the 1970s oil crises, nuclear incidents, or even war times, as researchers in the transition studies, we must carefully observe whether the crisis initiated radical changes in the subsequent energy choices, and how those choices were based on whose/what expectations of the "ideal future."[234] For instance, this dissertation found that the second hit oil crisis in the late 1970s had a much more substantial impact on Taiwan's carbon-intensive infrasystems than the more famous crisis of 1973-1974.

This point of abandoning the post-crisis argument is also valuable for environmental justice studies while discussing energy transition. Considering the relatively huge sunk cost of infrastructural transformation, or even relocation, often the original residential communities or humpback dolphins, migrant birds, and algal reefs, in the cases of this dissertation, would be asked to exchange their homes to enable extending renewable infrastructure, oil/gas facilities, and power plants to support far away industrial users. The recent 2014 vapor explosion incident in Kaohsiung City caused numerous casualties throughout the city's downtown due to the leak of a corroded underground pipeline, also warning of the long-time entangled risks buried underground via shared linkages among the intensive energy

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[234] This dissertation uses the term "energy futures" to describe the varied conceptions and expectations from a specific energy mix, which might lead society to sustain challenges such as oil crises, global warming, or national security crises. See for example, Lisa Suckert and Timur Ergen, "Contested futures: Reimagining energy infrastructures in the first oil crisis," *Historical Social Research* 47, no. 4 (2022): 242-66; Sakari Höysniemi, "Energy futures reimagined: the global energy transition and dependence on Russian energy as issues in the sociotechnical imaginaries of energy security in Finland," *Energy Research & Social Science* 93 (2022): 102840, 1-13.

infrasystems. The injustice and invisible risks embedded in the tightly coupled infrasystems need more discussions.

This brings me to my second suggestion for future research. My dissertation looks explicitly into the changing landscape of Kaohsiung Port-City to detail the formation of Taiwan's carbon-intensive network. As Carola Hein's concept of "petroleumscape" from her early works in architectural and urban planning history also hints, adding a layer of oil to the existing energy structure in a certain society shapes and is shaped by "the hybrid, multiple, shifting, and uneven ways in which many actors collaborate to create the global petroleumscape." [235] A further discussion regarding Taiwan's position in the global petroleumscape might enrich our understanding of the past transition from coal to oil in a broader global context as well. On the other hand, how the global petroleumscape adapts itself to the present-day renewable transition is still under-researched – as seen, for instance, in the entanglements of increasing demand for extra space for assembling and transporting offshore wind turbines at the port with ports' ongoing centrality to the petroleum network.

Finally, another important direction would be to look more closely at the *digital* infrasystems that are entangled with Taiwan's and other country's energy systems.[236] Visioning energy futures relies upon energy surveying and forecasting expertise. Computing techniques and energy forecasting technologies were essential for engineers to gather information on power flows in operating and planning the expansion of power systems. A change in the calculation method of power plants' economic viability could also explain how the engineers perceived differently regarding certain energy sources. Furthermore, managing the coordination among turbines of different operational costs and planning the reserve margin based on various power scenarios is the key to optimizing system output with the newly joined nuclear units. The development of computing technology helped TPC engineers encapsulate the complex factors and produce convincing forecasts to persuade the cabinet and public of the need for their nuclear power project and system expansion. The later high-speed digital computers feasible for applications in the mid-1950s greatly influenced nuclear engineering and should, thus, not be left out in understanding the history of nuclear power.

In short, computing devices enabled engineers to deal with complex data with abstraction and encapsulation of social realities. They increased engineers' ability to envision and manage complex fuel factors and social realities into econometric models for planning future expansion and decision-making. Yet, the determining logic of "economic viability" was rooted in how the engineers and managers conceived the social reality and international circumstances unfolding before them. As Thomas Baumgartner and Atle Midttun explained in their early paper and later edited book surveying energy forecasting practices in Western

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[235] Carola Hein, *Oil Spaces: Exploring the Global Petroleumscape* (Routledge, 2021), 300.

[236] Rebecca Slayton, "Efficient, secure green: Digital utopianism and the challenge of making the electrical grid "smart"," *Information & Culture* 48, no. 4 (2013): 448-78.

Europe and North America, "...although past establishment modeling and forecasting have been curiously apolitical, they cannot escape the political consequences of this neglect."[237] The different computing devices shaped their views and operations and, thus, directed the hybrid system. This is also a global trend that coincides with the first oil crisis in that the amount of available computing power experienced a steady increase and a rapid fall in computing cost. Therefore, TPC's data collecting and computing expertise deserves future study, for their experience represents another aspect of technology transfer in early post-war East Asia in developing their computing techniques. Such a study could also enrich our understanding of the often-subtle picture of TPC's long-term planning logic for energy transitions over time.

5.4 Concluding remarks

In this concluding chapter, I reflected on the empirical findings of this dissertation by going over the research themes that tie the preceding chapters together. Based on the recent controversy over CPC's third LNG terminal construction, I introduced a brief case study to supplement my argumentation. Unpacking the vested interests of such a national energy project helps this chapter to develop an additional question to close this dissertation: is Taiwan's renewable transition a break from its energy past or a temporary settlement?

After revisiting Taiwan's past energy transitions, my answer tends to be the latter. It is perhaps not only the case for Taiwan but also for other carbon economies. Nevertheless, it does not mean that efforts to transform both energy and politics are unimportant. On the contrary, such efforts pressure the mature infrasystems, such as TPC, CPC, and harbor facilities, to undergo a series of adaptations to fit the needs of society and future scenarios. For system builders such as TPC, the system’s low operating reserve due to past decisions has presented TPC with significant challenges for accommodating the growing capacity of distributed power generators into the system. It will require fast-response ancillary services from fast start-up power units to energy storage systems in coordination with automatic frequency control to prevent sudden power loss/increase in the grid within seconds. Accordingly, TPC's forecasting capacity is to expand to a more delicate system regarding different time horizons ranging from within 10 seconds, minutes, and hours to a day ahead.

To increase the system flexibility and prepare for the future breaking up of TPC's power generation and transmission sectors, TPC recently launched Taiwan's first energy trading platform in 2021 for day-ahead ancillary service and electricity reserve capacity transactions. Chapter 4 also discussed TPC's changing grid-enhancing strategy from building another extra-

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[237] Thomas Baumgartner and Atle Midttun, eds., *The Politics of Energy Forecasting: A Comparative Study of Energy Forecasting in Western Europe and North America* (Clarendon Press, 1987), Pages; Atle Midttun and Thomas Baumgartner, "Negotiating energy futures: The politics of energy forecasting," *Energy Policy* 14, no. 3 (1986): 219-41.

high-voltage transmission line in the late 1990s to improving the resilience of regional grids with more substations and distributing lines under the DPP's renewable transition policy. Although the tightly coupled carbon-intensive infrasystems may remain in place, the sociotechnical implications of these energy practices should also be expected and discussed in the future.

In other words, one should not view Taiwan's renewable transition as a farewell to its energy past; one should instead look at how renewable energy technologies evolve within entrenched carbon-intensive networks. In turn, we must consider the risks and opportunities behind deploying different energy sources through the power grid, ports, and oil/LNG networks on land and submarine pipelines. In order to reveal the complexity of the energy system and its interaction with other systems, my dissertation highlights the need for a comprehensive evaluation from a long-range and integrated infrasystems perspective.

Applying this analytical approach to comprehend the global island's past energy decisions offers a lens to observe how the tendency toward a high dependency on imported fossil fuels emerged over the course of the nation-(re)building of an isolated island country that is also the pivot point of the global economy at the same time. As this dissertation illustrated, Taiwan's energy history is a national history, but not merely a story about the interventions and responses of a robust developmental state. Transnational consultants, statesmen, engineers, nuclear physicists, industrialists, politicians, coal miners, fishermen, and nonhuman actors engaged intensively with each other in counteracting the multifaced challenges in Taiwan's multiple energy transitions.

Recognizing the rise and fall of their visions of an ideal energy mix from the aspect of system configuration could enrich our understanding of the energy pasts. Perhaps more importantly, it would help to see the present dilemma not in the forms of brown versus green energy but of the long-existed and unjust risk distribution problems and power struggles within carbon-intensive networks.

List of figures

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Impact Paragraph

This dissertation begins as a case study of Taiwan's energy history, but as the story unfolds, it becomes clear that Taiwan's energy transitions over time also offer scholars a glimpse at the complicated energy practices in post-war East Asia. Such a perspective is substantial as the current transition studies and energy history research focus on areas such as Europe, the Americas, or the emerging economies in the Global South. Yet, how to sell a study of Taiwan's energy pasts to different researchers remains a major task. Moreover, in terms of public relevance, how does studying the global island's energy pasts generate innovative discussions or even interventions on energy issues in reality?

During the PhD, I found my research interest in carbon-intensive infrasystems not only shared common interests with the researchers working on Taiwanese history in the Cold War era or transition studies in general but also echoed the concerns of people outside the academic circle, such as renewable energy developers, government officials, and NGOs. I pitched my ideas and exchanged them through presenting at academic conferences, such as the annual conferences of the Taiwan STS Association, the European Association of Taiwan Studies, the European Sociology Association, the Taiwan Society for Anthropology and Ethnology, the Powering East Asia conference, the Development and Interaction of Modern and Contemporary Humanities Network in Northeast Asian Sea Region conference, and the International Conference on the History of Science in East Asia. Additionally, I attended the Doing Energy History in Times of Transition workshop and the summer school held by the Électricité de France. In so doing, I was able to share the historical insights from my studies with a broader audience of researchers from different disciplines for further collaboration.

Another important opportunity that helps to expand my research network and the public relevance of my PhD study is through scholarship applications. For example, I was granted the Green Energy Scholarship by Ørsted in 2019. The program's establishment is to exhibit the foreign OWE developers' long-term commitment to the local society, and Ørsted managed to launch several social engagement projects. This gesture was also for exchanging trust and enhancing communication with the communities near the coast of Changhua County. The Green Energy Scholarship Program aims to stimulate more undergraduate or graduate students into the field of OWE technologies while showing its priorities for enrolling students originally from Changhua County. With this scholarship, I got opportunities to interview important stakeholders through their channels and build up research networks with early career researchers sharing the same research interests but across engineering and social sciences disciplines.

As for collaboration, since my study highlights the materiality of energy carriers/technologies and the circulation of knowledge within the engineering community, such an analytical approach allows me to join the collaborative project "The Taiwanese-Dutch

Connection in Historical Perspective." The project explores the connections between various Taiwanese and Dutch actors and their related cooperation and knowledge exchange in fields such as the semiconductor industry and harbor engineering. Within this project, my understanding of Taiwan's energy history and infrastructural system based on Chapter 2 offers a different perspective on the development of Taiwan's Kaohsiung port. My subsequent contribution was accepted in the forthcoming book *Since 1624*. Moreover, as I started to work with the Centre of Innovative Democracy in Taiwan while finishing up my dissertation, my idea of carbon-intensive infrasystems was further visualized in maps through their project "Kaohsiung Archive."[238] The archive will be a collective work based on the research method of collaborative ethnography. Various actors are invited to add materials and speak about their own experiences with the air pollutants and other environmental hazards caused by Kaohsiung's petrochemical industries over the years. My contribution is mainly the historical setting that denotes the importance of understanding history as the starting point of further social communication.

Overviewing the discussions I have had during the PhD, the most challenging part was not about convincing others of the importance of a historical understanding of the energy past to better grasp the complicated power relationships among various stakeholders in today's energy disputes. Instead, the question is: what is next? The "Theater of Negotiations" project held in Taiwan by STSers, sociologists, and anthropologists allows me to utilize my understanding based on Chapter 4 in actual social practices. The general idea of "theater of negotiations" is an educational experiment that combines the techniques of art, drama, and performance and brings students together to play and act as different stakeholders such as lobbyists, judges, NGOs, local politicians, residents, and non-human actors, etc., and debate specific controversial issues in a public space.[239] The offshore wind power construction dispute was one of the issues in the 2020 Theater of Negotiations, held at the Taipei Fine Arts Museum. Such an experiment carries both educational purposes and the possibility of generating new ways of thinking and dealing with controversies. In November 2023, the original organizers set the stage again with offshore wind energy as the major theme. I joined their fieldwork in advance and documented their performance (Figure 22). In so doing, I experienced and learned from such an innovative experiment; on the other, I was able to contribute my observation of the OWE controversies and to further stimulate more discussions regarding the uncertainty of scientific standards and perceptions of underwater noise, fishing stocks, impacted species, and human-non-human relationships through writing their press releases.

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[238] For more information, please see the ASTHMA FILES website, https://theasthmafiles.org/content/kaohsiung/essay

[239] Bruno Latour was invited to co-curate the Taipei Biennale in 2020. As in terms of on “another planet,” the Taiwanese STS association managed to bring the project “theater of negotiations,” which has been carried out in Paris once to Taiwan. See discussion in Paul Jobin and Tzung-Wen Chen, "Toward an Upgrade of Gaia-politics: A View from the East Asian Critical Zone," *Science, Technology, & Human Values* (2023).

Figure 22 A scene from the Theater of Negotiation in November 2023.

Students acted as a chairman of the local fishermen association (on the left) and a representative of OWE developer (on the right) in a staged public meeting. The umbrella symbolized the fishermen's association's welcome for sharing the profits in the future together.

Sources: Photographed by the author.

Summary

This dissertation provides a historical review of Taiwan's multiple energy transitions after the Second War. The main research question is: what drives a hydropower-based island country to a carbon-intensive system and shapes the ensuing renewable transition? Shifting focus from policy reviews to the engineers' diverse perspectives and practices, this research can offer a dynamic view of how Taiwan's energy futures were envisioned over time. The first part explains the growing dependency on fossil fuel-powered generators in the 1960s through discussions among Taiwanese engineers, US consultants, and other transnational experts. Even when facing the turbulence of the oil price shocks and the diplomatic crisis in the 1970s, Taiwan had not given up using oil. Instead, over 50 percent of electricity had been generated from fuel oil. Oil-fired generators' share of total installed capacity peaked at 80 percent in 1977. The statistic is contrary to the main TPC's discourse of the need to manage energy scarcity by diversifying energy sources to justify the subsequent installation of nuclear power plants. The explanation of the path dependence of carbon lock-in constitutes the dissertation's first part.

The second part looks into what changed TPC engineers' mindset to increase the percentage of electricity generation from renewable sources within its system. The quest begins with a story of an engineer's trip from TPC's maintenance factory to the UN's first international conference on alternative energy technologies in 1961. It first explains that TPC's initial interest in harnessing wind power was to utilize it in a diesel-based power system on Penghu Island in case a declaration of emergency during wartime might leave military bases out of fuel and power. The experimental nature of wind power projects and limited resources for dealing with maintenance issues did not make it a feasible option for TPC. Facing the social upheavals against TPC's expansion agenda, TPC found help from the cogeneration units and facilitated Taiwan's first electricity market deregulation in the early 1990s to promote their installations. On the other hand, deregulation also paved the way for the future integration of decentralized renewable units and the emergence of renewable developers who became the lobbyists in helping to pass the government's bill of renewable transition in the 2000s.

After the 2011 Fukushima Incident, Taiwan's renewable energy development became even more closely tied to the controversial nuclear units. The 2017 amendment of the Electricity Act symbolized the starting point for Taiwan's energy transition for demanding a substantial transformation in terms of market design, regulation, and TPC itself. The subsequent setbacks to renewable transition from the 2018 referendums' result suggest the unstable situation of the energy future. That is, the energy vision needs stable policy support to keep up the pace of the transition. Outside the parliament, to understand what enlarging renewable generated electricity to 20 percent of the total generation in Taiwan entails for the local society and the existing carbon-intensive network, the remainder of the second part examines the sociotechnical impacts brought about by onshore and offshore wind projects. In

turn, to prepare for the extensive wind penetration, the TPC system underwent several structural arrangements of the existing carbon-intensive network to accommodate such energy technologies. Taiwan's current energy transition exemplifies how renewable energy systems evolve within an entrenched carbon-intensive network.

Samenvatting

Dit proefschrift geeft een historisch overzicht van energietransities in Taiwan na de Tweede Wereldoorlog. De belangrijkste onderzoeksvraag is: hoe transformeert een eilandstaat van een systeem gebaseerd op waterkracht tot een fossielintensief systeem, en hoe wordt vormgegeven aan de daaropvolgende transitie richting hernieuwbare energie? Door de focus te verschuiven van beleidsbeoordelingen naar de uiteenlopende perspectieven en praktijken van ingenieurs, geeft dit onderzoek een dynamisch beeld van hoe de energietoekomst(en) van Taiwan in de loop van de tijd werd voorgesteld. Het eerste deel laat de groeiende afhankelijkheid van generatoren op fossiele brandstoffen in de jaren zestig zien door middel van discussies tussen Taiwanese ingenieurs, Amerikaanse consultants en andere transnationale experts. Zelfs toen Taiwan werd geconfronteerd met de turbulentie van de olieprijsschokken en de diplomatieke crisis in de jaren zeventig, gaf Taiwan het gebruik van olie niet op en werd meer dan 50 procent van de elektriciteit opgewekt met stookolie. Het aandeel van oliegestookte generatoren in de totale geïnstalleerde capaciteit bereikte in 1977 een piek van 80 procent. Dit gegeven lijkt in strijd met het belangrijkste discours van de TPC: de noodzaak om de energieschaarste te beheersen door energiebronnen te diversifiëren en onder meer de bouw van kerncentrales te rechtvaardigen. De verklaring van de padafhankelijkheid van koolstof lock-in vormt het eerste deel van dit proefschrift.

Het tweede deel van het proefschrift onderzoekt wat leidde tot de mentaliteitsverandering van TPC-ingenieurs om het aandeel van hernieuwbare bronnen binnen het elektriciteitssysteem te verhogen. De zoektocht begint met het verhaal van de reis van een ingenieur van de onderhoudsfabriek van TPC naar de eerste internationale conferentie van de Verenigde Naties over alternatieve energietechnologieën in 1961. In eerste instantie had TPC interesse in het benutten van windenergie was om deze te gebruiken in een op diesel gebaseerd energiesysteem op Penghu-eiland. Het experimentele karakter van windenergieprojecten en de beperkte middelen voor het omgaan met onderhoudsproblemen maakten het op dat moment geen haalbare optie voor TPC. Geconfronteerd met de sociale onrust tegen de uitbreidingsagenda van TPC, vond TPC hulp van de warmtekrachtkoppelingseenheden en faciliteerde begin jaren negentig de eerste deregulering van de elektriciteitsmarkt in Taiwan om hun installaties te promoten. Deregulering maakte ook de weg vrij voor de toekomstige integratie van gedecentraliseerde duurzame eenheden en de opkomst van duurzame ontwikkelaars die de lobbyisten werden bij het aannemen van het wetsvoorstel van de regering voor de transitie naar duurzame energie in de jaren 2000.

Na het Fukushima-incident in 2011 raakte de ontwikkeling van hernieuwbare energie in Taiwan nog nauwer verbonden met de maatschappelijke controversie over kernenergie. De wijziging van de Elektriciteitswet uit 2017 symboliseerde het startpunt voor de Taiwanese energietransitie, omdat het een substantiële transformatie eiste op het gebied van

marktontwerp, regulering en TPC zelf. De daaropvolgende tegenslagen voor de transitie naar hernieuwbare energiebronnen als gevolg van de uitslag van de referenda van 2018 wijzen op de onstabiele situatie van de energietoekomst. Dat wil zeggen dat de energievisie stabiele beleidssteun nodig heeft om het tempo van de transitie bij te houden. Om buiten het parlement te begrijpen wat het vergroten van de hernieuwbare opgewekte elektriciteit tot 20percent van de totale opwekking in Taiwan inhoudt voor de lokale samenleving en het bestaande koolstof intensieve netwerk, onderzoekt de rest van het tweede deel de socio-technische gevolgen die worden veroorzaakt door onshore en offshore windenergieprojecten. Ter voorbereiding op de uitgebreide windpenetratie onderging het TPC-systeem op zijn beurt verschillende structurele arrangementen van het bestaande koolstof intensieve netwerk om dergelijke energietechnologieën te huisvesten. De huidige energietransitie in Taiwan illustreert hoe hernieuwbare energiesystemen zich ontwikkelen binnen een diepgeworteld koolstofintensief netwerk.

Curriculum Vitae

Tsaiying Lu is a researcher who completed her BA and MA in Sociology at National Chengchi University. She worked as a research assistant at Academia Sinica after finishing her studies from 2016 to 2018. Her research interests began with studying how society perceives and plans towards achieving "sustainability," with a particular focus on projects such as green technologies. Her master's thesis explored how Taiwan's bike-sharing system (YouBike) co-evolved with the urban infrastructural system, such as the MRT and biking routes. She illustrated the sociotechnical transformation by studying the operational logic of the bike manufacturer, Giant. This thesis was awarded the Outstanding Master Thesis by the Taiwanese Sociological Association in 2016. In 2018, she received the Government Sponsorship for Overseas Study scholarship and began her PhD program at Maastricht University. There, she learned how to further her research interest in analyzing the obstacles and controversies of Taiwan's current renewable transition by applying both STS and historical approaches. Her PhD project was awarded the Green Energy Scholarship Program by the Danish offshore wind developer, Ørsted, and the History of Electricity and Energy Research Grant by Électricité de France (EDF). After relocating to Taiwan in late 2023, she worked as a researcher on the collaborative project between TPC and the Centre for Innovative Democracy (CID) called "Social Communication for Nuclear Waste Site Selection." She also contributed to the collaborative ethnography project, “Kaohsiung Archive.”