Green Power Generation and the Evolution of the Chinese Electricity Industry, 1880 to the present

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Abstract

Climate change urgently calls for fundamental changes in the way we generate electricity. As the world's largest electricity generator and the biggest greenhouse gas emitter, China has pledged to decarbonise its power system. The success or failure of its efforts to rapidly accelerate the deployment of renewables will have immense implications for the global green transition. How might China meet its energy needs using green energies? This is the question this thesis takes up. This thesis uses mixed methods to address change through time as means to understand where China is now in terms of energy and where it might go next.

This thesis begins by applying Hughes's system approach to investigate the evolution of China's power system from its origins in the 1880s to the current green transition. The findings show that the Chinese power system originated in wars, was built by the Western-educated elites, embedded with the socialist-style gained from Soviet assistance, and directed by the central state's political and economic principles. As a late developer, the case of China indicates the importance of human capital and that political, economic and educational openness are necessary conditions for late development.

The thesis then focuses on the subnational political economy of the power system's green transition through an in-depth case study. The findings of a neo-Gramscian analysis demonstrate the dynamic processes and evolving power relations of the local electricity industry's green transition. The results point out that the rivalling coalitions of distinct economic interests – the established coal-fired power historical bloc and the young renewable energy firms – were particularly central to the process.

The final themed chapter examines whether it paid to adopt renewable energies in Chinese electricity generation firms from 2005 to 2017. The quantitative results show that adopting renewable energy positively impacts corporate profitability. Profitability is more stable and increases faster in firms with a higher share of renewable energies. Qualitative investigations reveal that the state-owned generators now strive for profits rather than scale, and private generators prioritise innovation and political prestige over profitability.

Table of Contents

List of Tables

List of Figures

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Signature:

Abbreviations

AC	alternating current
AI	Artificial Intelligence
BECCS	bioenergy with CCS
CCP	Chinese Communist Party
CCS	Carbon Capture and Sequestration/Storage
CCTV	China Central Television
CEC	China Electricity Council
CFC	chlorofluorocarbons
CHP	combined heat and power
CNY	Chinese Yuan reminbi
COP	UNFCCC Conferences of Parties
CPIA	China Photovoltaic Industry Association
DC	direct current
EIA	Environmental impact assessment
ESG	Environmental, Social and Governance
EV	electric vehicle
FDI	foreign direct investment
FGD	glue gas desulphurisation
ESP	electrostatic precipitator
FYP	Five-Year Plan
GHG	greenhouse gas
GW	gigawatt
ICT	Information and Communication Technology
IEA	International Energy Agency
IGCC	Integrated gasification combined-cycle
IPCC	Intergovernmental Panel on Climate Change
IPCC AR5	Fifth Assessment Report of the IPCC
kWh	kilowatt hour
LCOE	levelised cost of electricity/energy
MEE	Ministry of Ecology and Environment
MEP	Manchuria Electric Power Joint Stock Company
MLP	Multi-Level Perspective
MOF	Ministry of Finance

MOST	Ministry of Science and Technology
Mt	million tonnes
MW	megawatt
NDRC	National Development and Reform Commission
NEA	National Energy Administration
PBoC	People's Bank of China
PM 2.5	particulate matter with a 2.5-micrometre diameter
PPA	power purchase agreement
PRC	People's Republic of China
PV	photovoltaics
ROA	Return on Assets
SASAC	State-owned Asset Supervision and Administration Commission
SC	supercritical
SCR	Selective catalytic reduction
SDPC	State Development and Planning Commission
SERC	State Electricity Regulation Commission
SETC	State Economic and Trade Commission
SOE	State-owned enterprise
SPC	State Power Corporation
TEP	Techno-Economic Paradigm
TVE	township-village enterprise
TWh	terawatt hour
UHV	ultra-high voltage
USC	ultra-supercritical
UNFCCC	United Nations Framework Convention on Climate Change
WBG	World Bank Group
WTO	World Trade Organisation

Chapter 1 Introduction

1.1 Climate change, power sector, and China

Despite clear evidence of human-induced climate change,[1] pledges and efforts government made, and the prevalence of clean, economical and sustainable energy options, energy-related carbon-dioxide emissions have increased 60 per cent in total since the signing of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 (IEA, 2021a) and increased 1.3 per cent annually on average after the ratification of the Paris Agreement in 2015 (IRENA, 2019). The gap between observed emissions and the reductions needed to limit the rise in global temperatures to 1.5 degrees Celsius and avert the worst effects of climate change is widening. The energy sector is responsible for almost three-quarters of the emissions that have already pushed global average temperatures 1.1 degrees Celsius higher since the pre-industrial age (IEA, 2021b). As the primary source of global emissions, the energy sector also holds the key to mitigating climate change. All mitigation scenario studies in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5 report) reached the conclusion that combating climate change requires fundamental changes in the global energy supply systems, including the decarbonisation of power generation and the substitution of electricity for direct use of fossil fuels across sectors (IPCC, 2014). In addition, most scenarios in the IPCC AR5 report a continuation of the global electrification trend in the future. Thus, the electricity sector plays a central role in mitigation scenarios with deep emissions cuts.

When it comes to the electricity industry, no country generates such bittersweet superlatives as China. China has achieved remarkable economic growth over the past decades, from the world's poorest country to the world's second-largest economy. Such unprecedented growth propelled electricity demand. With abundant coal supplies in China, coal-based power generation was ramped up to meet electricity demand rapidly. China's power system has grown to be the

[1] The United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defined climate change as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods' (UNFCCC, 1992, p. 7).

largest in the world. At the same time, it emits more carbon dioxide than any other country. The electricity industry is the single largest source of the country's carbon dioxide emissions and is the decisive area to tackle climate change.

On the global level, electrification of the energy system, historically, was a crucial driver of the historical energy transformation from an originally biomass-dominated energy system in the 19th century to a modern system with high reliance on fossil fuels, especially coal and gas – the two major sources of electricity generation today. On the other hand, electricity generation is the largest single sector emitting carbon emissions worldwide. Thus, as electricity becomes the core of the energy system, decarbonising the power system is at the heart of the solution to climate change and becomes urgent. While the thesis is proceeding, many countries have announced new commitments to reach climate goals. In the run-up to the 26th Conferences of the Parties (COP 26) of UNFCCC, more than 50 countries and the entire European Union have pledged to meet net-zero emission targets. Achieving the net-zero emission target requires both a significant increase in electricity needs and a radical transformation in how electricity is generated. The International Energy Agency (IEA)'s recent landmark report indicates that, in the global pathway to net-zero emission, total electricity generation needs to increase by over 250 per cent between 2021 and 2050 to meet the rapid electrification of energy, transport, building sectors (IEA, 2021a). By 2050, electricity will account for almost half of the global total energy consumption, 90 per cent of which has to come from renewable sources (wind, solar, biomass, hydro, and geothermal) (Greenblatt et al., 2017) and the rest from nuclear and fossil power with carbon capture and storage technology (CCS) (IEA, 2021a).

All these values indicate that we are on an irreversible way to decarbonise the power system. The path of the Chinese electricity industry shapes the landscape of power generation globally and is an essential solution for combating climate change if paired with clean electricity. It is thus vitally important to understand the Chinese power system – the underlying historical, political, economic, social, and cultural factors and the intertwined relations that build the system and enable transitions to proceed.

Changes have been happening. China has spent more cleaning up its power supply system than America and the European Union combined (TheEconomist, 2020c). Its electricity sector has become the platform for rapidly developing and scalable green technologies. China has produced 72 per cent of the world's solar modules and 45 per cent of global wind turbines and is the world's largest installed capacity of land-based wind power and solar PV (IEA, 2018). In 2015, China committed that its carbon emissions reach a peak by 2030. In September 2020, China's President Xi Jinping made a statement to the United Nations General Assembly that China would strive for carbon neutrality – a balance between carbon emissions and carbon reduction – by 2060 (IEA, 2020b; TheEconomist, 2021). China's goal of net-zero emissions potentially represents 'the biggest climate undertaking ever made by any country' (IEA, 2020b). It must descend from its emissions peak far more rapidly, within 30 years, than any other major economy has accomplished (or pledged to do) in 50 to 60 years (Levin & Rich, 2017; TheEconomist, 2020b). To achieve the net-zero target, China needs to completely decarbonise its electricity industry, which still installs more than 1,000 gigawatts (GW) of coal-fired generating capacity taking up 49 per cent of the global coal-fired electricity (TheEconomist, 2020a, 2020b). The transition from coal-fired power generation to renewables is happening in China, but China needs to scale up the green power generation sources considerably faster. Wind and solar will have to do a lot of the heavy lifting, with deployment significantly exceeding the 2018 peak year after year (IEA, 2020b).

A fundamental and rapid transformation of the power generation sector could bring substantial benefits to China and the world. Due to the scale of the Chinese power system, its decarbonisation can help international efforts for more robust climate mitigation. An accelerated transformation of the Chinese power system could bring significant benefits in the drive to limit climate change in line with the Paris Agreement. China can use the path of power system transition to make accelerated progress in restructuring its economy towards a pattern of growth in advanced high-quality industrial sectors while making clean energy technologies affordable for countries around the world, particularly developing countries which will see a rapid increase in energy demand over the coming years. Thus, it is crucial to evaluate the potential mechanisms for the power system's green transition. And for that, this thesis invokes history to understand the critical characteristics of the Chinese power system and the actors who constructed the energy regime. Such historical dimensions of this thesis are of particular importance in conducting the assessment, as shown in the following Chapters 2, 3 and 4.

This thesis focuses on the electricity generation sector's transition from fossil fuels to renewables, mainly onshore wind and solar photovoltaics (PV) power. Although the electricity sector could be largely decarbonised with the CCS deployment, CCS remains at an early stage of commercial use, only being equipped in two commercial power plants globally over the past five years (IEA, 2021a). CCS is constrained by concerns of potential ecological impacts, accidental release of carbon dioxide, and related storage effectiveness of CCS technologies (IPCC, 2014). Regarding nuclear power, more outstanding efforts will be necessary to improve the safety, uranium utilisation, waste management, and proliferation concerns of nuclear energy use (ibid). Considering the large up-scaling in the mitigation scenarios, global technical potentials of biomass and hydropower seem to be more limited than for other renewables. Thanks to falling costs, widespread availability, technological enhancement, and policy support across countries, solar PV and wind lead the deployment of renewables in the power system. Between 2010 and 2015, global wind-driven generation had increased about two-and-a-half times, and solar generation had grown nearly eightfold (Smil, 2018); and wind and solar PV are projected to dominate the total installed capacity additions of renewables in the following decade (IEA, 2021b). I use *renewable* and *green* interchangeably to describe energy or technology in the thesis. However, *green* will be used more often to present the dynamics of the process rather than merely a static result. Also, on semantics, the change from fossil fuels to renewable energy is often referred to as energy *transition* or *transformation*, sometimes *evolution*. I use *transition* and *transformation* interchangeably in this thesis.

1.2 Existing studies and research gaps

The fundamental and rapid transformation toward a low-carbon energy system has received increasing attention both in the policy arena (as discussed above) and in social sciences research (Loorbach, Frantzeskaki, & Avelino, 2017; Markard, Raven, & Truffer, 2012; Smith, Stirling, & Berkhout, 2005). The profound process of shifting from fossil fuels to renewables has been known as the *energy transition*, or so-called *green transformation* (Peter Newell, Paterson, & Craig, 2020) or *sustainability transition*, which Markard et al. (2012) define as 'long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption', and such a shift involves 'far-reaching changes along different dimensions: technological, material, organisation, institutional, political, economic, and socio-cultural' (p. 956). Researchers further intimately link the transition to the political, social, and cultural institutions within the situated societies (Pearse, 2020) and underline that accomplishing green transformation is indeed a significant political-economic transformation (Peter Newell et al., 2020; Scoones, Leach, & Newell, 2015). Chapter 3 offers a detailed review of the existing transition studies.

In general, there are four characteristics of the green energy transition. First, it is multi-dimensional. It entails technological changes across entire value chains and links to the political, social, and cultural institutions within the situated societies (Kern & Markard, 2016; Pearse, 2020). It is a 'phase-out/phase in process' (Bromley, 2016, p. 167), involving both 'the decline of incumbent industries' and 'the rise of new ones' (Fouquet, 2016, p. 9). Second, energy transition is associated with a high degree of indeterminacy in terms of the involvement of a diversity of actors and high context-dependency. Such multi-dimensionality and uncertainty indicate that pathways vary with contexts, requiring goal formulation, novel and flexible tools and collaboration across different scales, from local to national and international (Kern & Markard, 2016; Peter Newell et al., 2020). Third, the ongoing energy transition is purposive. It is a purposive transition towards sustainability that targets carbon emission reductions and more sustainable modes of energy production and consumption (Kern & Markard, 2016). Thus, the ongoing green transition requires more government interventions compared with past energy transitions that have emerged due to new resource and technologies discoveries, for instance, from wood to coal. Fourth, it is urgent. The climate emergency requires rapid energy transition (Geels, Sovacool, Schwanen, & Sorrell, 2017; Roberts et al., 2018; Sovacool, 2016).

Among the wide range of transition studies, a great deal of research has used historically informed approaches to understand transitions. As the climate emergency calls for disruptive changes in the current carbon-intensive economy and the pressing need for transition to a low-carbon economy, there is increasing interest in seeking to draw lessons from historical precedents of large-scale, disruptive, deliberate, and rapid changes that might offer relevant parallels to grappling with the contemporary climate crisis. Some scholars seek historical big technological transitions to formulate frameworks to understand the structures of transition, such as Geels (2002), Geels and Schot (2007), and Perez (2002) (see Chapter 3). Some scholars invoke history to seek the factors that led to a change. Allen (2012) and Fouquet (2010) found that cheaper or better services were the key drivers of the transition from biomass to fossil fuels. In contrast, Malm (2016) challenged the 'cost-centric' view, which seems to be the consensus among many historians like Smil (2016, 2018) and also the analysts drafting reports in IEA.[2] Malm argued that the profit accrued from fossil fuels, not their cost, was the key to the replacement of water with coal. His argument that profit is the key to a successful transition also has implications for the ongoing green energy transition. As it can be seen from the findings of case studies of the local energy transition in Chapters 3 and 4, higher profitability of the renewable energy projects than the coal-fired power plants is the primary reason for the local generators shifting their investment away from the conventional coal-fired power projects towards renewable ones. Thus, these findings suggest that policymakers need to optimise the investment environment and create a market environment that is more conducive to improving profits for green energy projects. Some scholars look for existing experiences to develop an understanding of the agency and relations of power that enabled and frustrated changes (Peter Newell, 2015; Peter Newell & Simms, 2020; Pearse, 2020; Hubert Schmitz, 2016).

Historically informed approaches to understanding transformations are helpful and necessary. However, most of the investigations were conducted in the developed regions with capitalist economic and political systems. The Industrial

[2] In most of IEA's reports on predicting a rapid energy transition, it finds encouragement in the cost of the respective energy types. They consider a rapid transition more achievable as renewables get cheaper than hydrocarbons.

Revolution is most frequently referenced when seeking historical parallels for the energy transition (Allen, 2012; Fouquet, 2010, 2016; Huber, 2009; Malm, 2013, 2016). References are also often made to Fordism (Peter Newell, 2015) and the Information Age (Perez, 2015) (see also studies by Smil (2016) and Sovacool (2016), which involve multiple case studies). Studies have focused heavily on the United Kingdom's past. This is understandable as it was the first economy to make a major energy transition. In addition, there is no precedent for a large-scale transition to a widely applicable low carbon economy. Thus, the history of the United Kingdom, or the United States (relating to Fordism and the Information Age) or some European countries, for instance, Germany's *Energiewende* offers useful insights on understanding transitions.

Nevertheless, they are all about green transformations in capitalism and in developed countries. How about the transitions in a socialist system and the late developing country – China? China is a country upholding socialism, or more precisely, socialism with Chinese characteristics (Xi, 2019), and is the crucial case of the late developer. Lessons from the British (or other capitalist and developed countries mentioned above) are not necessarily helpful. Thus, it is essential and valuable to seek precedents of destructive changes in the history of China and look for past and present experiences to understand what needs to be achieved to make transitions happen. China, de facto, is a good site for looking for historical cases of large-scale deliberate socio-technical, economic and political change. It has experienced radical reorganisations in the structure of the economy and politics: from a semi-feudal and semi-colonial country to a socialist society and then to socialism with Chinese characteristics, from a centrally planned economy to a socialist market economy. Also, changes that happened are on a large scale and with rapidity, taking the impressive growth of solar PV deployment in recent years as an example. China's goal of carbon-neutral, for instance, would represent a milestone in modern Chinese history comparable to the funding of the People's Republic of China in 1949. To achieve the net-zero-emission goal timely would require China to quickly embark on an ambitious effort to transform its economy, as it did after the Economic Reform and Opening Up in 1978. While history never identically repeats itself, it could offer highly relevant lessons about the circumstances in which transitions came about (Arnold, 2000). However, there is a surprising paucity of studies investigating China's power system, or the broader energy transition, from the retrospective perspective. This thesis seeks to address this gap.

Reviewing studies on China's electricity industry (see Chapter 2 and Chapter 3), very few studies have been conducted to explicate the origins of the Chinese power system. As Fukuyama (2011) wrote in his book *The Origins of Political Order:*

> Countries are not trapped by the past. But in many cases, things that happened hundreds or even thousands of years ago continue to exert major influence on the nature of politics. If we are seeking to understand the functioning of contemporary institutions, it is necessary to look at their origins and the often accidental and contingent forces that brought them into being. (p. x)

Similarly, to understand the contemporary power system, it is essential to look at its historical origins and investigate the complex historical circumstances under which the system was initially created. It could help us identify the systems' peculiarities and understand why some changes are difficult and others are easy under current circumstances. Chapter 2 gives an account of where the Chinese contemporary power system came from in the first place.

In addition to the insufficient historical dimensions of existing research, relatively little empirical research has been carried out on the electricity industry, especially at the local level and within the generators. Most of the publications (such as Andrews-Speed, 2016; Andrews-Speed & Zhang, 2019; L. Brandt & Rawski, 2019; Delman & Odgaard, 2014; Engels, 2018; Isoaho, Goritz, & Schulz, 2017; Kahrl, Williams, Ding, & Hu, 2011; Lester & Thomas, 2018; Lin & Purra, 2019; Yeh & Lewis, 2004) focused mainly on the formal policy landscape, statistics of the industry development, the trajectory of transition at the national level. What remains poorly understood is the change at the local level and the response of the business.

Though green transformation challenges are national and global, 'local solutions must always be forged' (H. Schmitz & Scoones, 2015, p. 14). While overall energy and climate-relevant policy directions continued to be set by the central government, localities were given greater leeway to explore the specific approaches and possible instruments to meet the state's objectives (M.

Schreurs, 2017). Considerable room is available for local innovation. Thus, lessons from a case where the rapid change happened could enlighten the current discussions of speeding up the transition on how, when, and why such change has previously taken place. Chapter 3 illustrates a historical process of accelerated changes in the local electricity industry.

The green transition fundamentally relies on the actions of business. A report revealed that over half of global greenhouse gas emissions from 1988 to 2015 were traced to just 25 corporate and state producing entities (P. Griffin, 2017). A recent study by Alova (2020) also showed that utilities' transition depends on a minority of companies, and utilities' transition to renewables remains slow, lagged behind and even hindered the global transition to renewables. It is necessary to locate the research focus on the generators per se. Studies have suggested that high renewable energy penetration is technically and economically feasible (IPCC, 2014; IRENA, 2020), plus supporting policies offered by the governments. Why has the pace of generators growing their renewables-based generation capacity remained slow? We can perhaps gain some insights from Malm (2013)'s attempts to understand why steam power could replace water in the British cotton industry. He explained the reason why 'steam gained supremacy in spite of water being abundant, at least as powerful, and decidedly cheaper' (p. 31) is that 'the reasonable expectation of an increment (that is, *profit*) in exchange-value' (p. 49). In the same vein, Perez (2002) argued that 'it is when the critical technological breakthroughs articulate them into … profitable business avenues, …, that … can become truly all-pervasive' (p. 13). Is this also the case for the Chinese generators? Is profitability the primary consideration when they make their decisions on holding back or actively building up renewable-based generation capacity? If not, what else? Could the generators get financial rewards from adapting their portfolios of power-generation assets to the energy transition after all? These lead to a long-lasting debate on 'does it pay to be green', which is examined and discussed in Chapter 4. A part of Chapter 3 also touches on some of the issues.

1.3 Research questions

This thesis seeks to shine new light on current discussions about the green transition with lessons drawn from the evolution of China's power system. The central research question in this thesis asks how, given its development of an energy regime since the 1880s and its present structure, might China power the country in a green way? Specifically, based on the discussions above, the investigation aims to address the following sub-research questions:

1. How did China's power system originate and grow into a world powerhouse? Who are the actors who strategically work to build the technology and network in China? What factors have driven the continuous change and growth of the power system?

2. How could a rapid green transition happen? Who and what have slowed and accelerated the electricity industry's green transition?

3. Does it pay to become green? What is the perception of 'pay' by different types of generators in the industry, and how has it changed through time?

1.4 Research design and methods

This thesis employs a mixed-method approach using case studies and multilevel models to analyse longitudinal data (see also Chapter 4). Mixed methods research involves collecting and analysing both qualitative (see especially Chapters 2 and 3) and quantitative data (see especially Chapter 4). Creswell and Tashakkori (2007) expanded the concept of mixed methods by identifying four different perspectives: methods perspective, in which multiple types of qualitative and quantitative data are collected, analysed and interpreted; methodology perspective, which focuses on the whole process of research, such as worldview, questions, methods, analysis and inferences; paradigm perspective, in which philosophical assumptions are the main focus and pragmatism is viewed as the most appropriate worldview for mixed methods; and practice perspective, in which the mixed methods strategies are viewed as a bottom-up approach and emerge in the process of conducting traditional research designs. Teddlie and Tashakkori (2010) added that mixed methods represent the 'methodological eclecticism', that is, 'selecting and then synergistically integrating the most appropriate techniques from a myriad of quantitative, qualitative and mixed methods to more thoroughly investigate a phenomenon of interest' (p. 10). This thesis embraces all the conceptualisations and recognises that a triangulation of multiple methods can break the methodological hegemony of one single method. Integrating two types of data in a single study provides a way to offset the drawbacks of using monomethod and highlights the advantages of using both approaches (Creswell & Plano Clark, 2018; Tashakkori & Teddlie, 1998). The findings from different methods would provide mutual confirmation and, thus, enhance the validity of the research results (Bryman & Bell, 2015; Molina-Azorín & López-Gamero, 2016).

This mixed methods research follows an exploratory sequence. The discovery part of mixed methods, involving a wide range of qualitative data collection, is associated with inductive logic. The primary intent of the exploration was to acquire a deeper understanding of the industry context, identify important variables, generate hypotheses that were tested using quantitative research, and overcome a major practical constraint of doing research in China – the accessibility of corporate operating and financial data. The explorative stage is essential as it involves creative insights that might lead to new knowledge (Teddlie & Tashakkori, 2010). Then the corporate data collected in the discovery stage were analysed using quantitative methods, and the qualitative testimonies also could be used to explain the quantitative results.

The research is based on field investigations carried out in China between 2018 and 2019. Appendix A presents the research design and procedures. A round of pilot studies was conducted first in three provinces located in north-eastern, central and western China. I conducted exploratory interviews with seven generators in the provincial capitals of these three regions. Meetings are worthwhile, through which I tested the feasibility for further in-depth studies, refined the interview questions (see Appendix B) mapped out the field inquiry. More importantly, it helped me locate the resources – both potential interviewees and written evidence. I encountered a great deal of resistance in conducting research in the western province, where the respondents seemed very conservative and reluctant to share specific corporate information. Thus, I decided to limit the investigation to the other two regions. In line with the historical specificity of this research, the case analysis sticks to the historical method paying attention to ‘gathering, criticising and verifying all the available sources’ (Evans, 2000, p. 19). Specific data collection and analysis could be found in Chapter 3 and Chapter 4, where Chapter 3 focuses on the qualitative aspects and Chapter 4 elaborates more on quantitative methods.

The biggest and most challenging task of this research is to identify sources. Given the historicity of the study, the written archival sources are what I desire. Leopold von Ranke, who is frequently represented as the father of modern historiography (Arnold, 2000), insisted on primary sources and avoided reliance on secondary sources generated after the events (Evans, 2000, p. 18). However, corporate and government records are barely available in China. Such constraint was also noticed by G. Jones and Comunale (2018), who point out that the absence of corporate archives is a striking feature across most emerging markets because 'in most countries, there was no tradition of maintaining archives … no tradition of opening archives to researchers' (p. 3). These are precisely the biggest obstacles to doing historical investigations in China. Nevertheless, they suggest that oral history can help fill the information voids arising from the scarcity of material in corporate archives. Thus, I took reference to the oral history, diaries and memoirs of the Chinese engineers and industrialists in the electrical industry and politicians (see Chapter 2), in-depth semi-structured interviews, conversations and presentations from industry conferences, workshops and seminars, and televised interviews. At the same time, I strived to collect supporting evidence from a wide range of documentary materials, including conventional government documents (see Appendix C), organisational reports and industry yearbooks (see Chapter 3), and some novel sources such as selected works of the Chinese leaders, the corporate archive of the company located in China and owned by foreign companies (see Chapter 2). Table 1-1 lists the data sources.

The empirical investigation is primarily based on in-depth semi-structured interviews with individuals in the local firms, government, and community. Previous work experience provides me with rich experiences and access to China's electricity industry, local government agencies, banks, and residents. The interview process went smoother than I expected. Interviewees generally appeared genuinely interested in answering my questions and enjoyed talking about their work and visions of China's electricity industry and its sustainable future. Especially when I visited the advanced coal-fired power plants and renewable energy power farms, respondents appeared to want to display their progress and achievements in deploying and upgrading the advanced technologies. The government authorities were willing to show their experience in promoting the local energy industry and other relevant issues, particularly those closely related to renewables. The interviewees from the commercial banks were open to discussion of the drawbacks of the financial products and policies. However, when asking permission to access the corporate operating and financial data, some of them refused. Though it posed some restrictions on the quantitative inquiries, as indicated in Chapter 4, the qualitative aspect of interrogations compensates for the limitations.

Category	Data source	Code	Number
Interview	Corporate manager-generator-SOE-provincial level	Csp	11
	Corporate manager-generator-SOE-city level	Cs	14
	Corporate manager-generator- private	Cp	6
	Corporate manager-generator-TVE	Ct	2
	Corporate manager-grid-provincial level	Rp	1
	Corporate manager-grid-city level	R	2
	Government officer-provincial level	Gp	2
	Government officer -city level	G	5
	Commercial bank-provincial level	Bp	3
	Commercial bank-city level	B	4
	Local resident	res	11
Document	Corporate financial and operating data-by participants (city level)		25
	Corporate financial and operating data-China Electricity Council and Bloomberg		
	Corporate annual report and CSR report		
	Local government document		
	Central state document		
	Reports by international organisations (IEA, IRENA, REN21, UN, WBG)		
	Local chronicles		
	Media release (video and written)		
	Diaries and memoirs		
	Selected works of Mao Zedong, *Xi Jinping: the governance of China*		
	Archives by Japan - *Forty-years Development of Manchuria*		
Others	Attendance at the industry conferences, workshops, and seminars (both online and onsite)		

Table 1-1 Overview of data sources

1.5 Contributions

The contribution of this research is fourfold. First, this thesis proposes a conceptual framework that builds on the concept of momentum to study the development and transformation of the Chinese power system. In doing so, the three elements of momentum – direction, mass, and velocity – are examined in detail by incorporating the concepts of energy sovereignty, system mass, historical bloc, and interest redistribution. I argue that energy sovereignty is the direction of the system's development; the mass of the system depends on the production capacity and technological capability, which are accumulated through learning by doing; the acceleration of the transition depends on the resultant force that results from the interactions of the actors and their power relations, which can be evaluated through examining the historical bloc; the final key to a rapid transition is in the hand of business actors whose interests are the centre of concerns. This framework contributes to studying the Chinese electricity industry and its green transition by examining the historical factors, path dependencies, and ongoing dynamics of the system. It allows for analysing structural change, power relations, and underlying interests of dominant actors, and investigating the particular context in which a transition happened, therefore offering insights into the ongoing energy transition. Such a framework, reconciling the insights of theories of socio-technical change, political economy, and business, contributes to a comprehensive analysis of a problem that is political, economic, social, and technological.

Secondly, it makes theoretical contributions in each main chapter. As indicated in the research questions, I attempt to contextualise the discussions in historical, political economy and business terms, which led to three independent chapters (Chapters 2, 3, and 4, respectively). I apply and test different theories in each chapter. Chapter 2 applies Thomas Parke Hughes (1983)'s systems approach, which he used to analyse the growing electric power systems in Western society from 1880 to 1930, to study the evolution of the power system in China from 1880 to the present. Despite the Western and Chinese electric supply systems growing in utterly different institutional contexts, they seem to follow similar pathways. Such a pattern provides valuable historically informed insights for current predicaments about accelerating a purposive and progressive energy transition. By applying the systems approach, this chapter explains not merely how historical change takes place but the direction in which all change moves. Chapter 3 applies the neo-Gramscian theory to study power relations. Its focus on the organisational, economic and ideological pillars of powers enable us to interpret the complex transition process better and understand and explain various actors' changing power relations and strategies in the current energy transition compared with other theories. In addition, the Chinese context provides a rich and multi-faceted backdrop to extend our thinking about business, government, and civil society and their roles and capabilities in enabling and accelerating large-scale change. The findings challenge the conception of the historical bloc and its implications on the energy transition, shedding light on an alternative path to the energy transition that does not necessarily require a fundamental shift in power relations. The fossil fuel historical bloc is transforming itself by adapting and incorporating renewable energies rather than being substituted by the emerging renewable energy actors as the rival group. Chapter 4 grounds the debate of 'does it pay to be green' in the fast-changing Chinese electricity industry. Considering the distinguishing features of the state-owned and private-owned firms in China delivers a refined understanding of payoff, which paves the way for designing new measurements of payoff for testing the effects of being green.

Third, this thesis contains novel empirical materials. It tackles the shortage of empirical research on China's electricity industry and brings original data, particularly data on the local power sector. This research will enhance our understanding of the growing Chinese power system and provide new insights into the green energy transition.

The last major contribution of this thesis is adopting mixed methods to assess and analyse the dynamic change that happened in China's electricity industry. It is one of the first investigations to employ the historical perspective to study China's power system. The study presented in this thesis is also one of the first attempts to use both qualitative and quantitative methods to test the effects of the electric generator's adoption of renewable energy on firm performance.

1.6 The structure of the thesis

This thesis is composed of three themed chapters: Chapters 3, 4, and 5. Each chapter aims to address the three sets of sub-questions, respectively. Though they are structured as three independent chapters, they are closely related. They represent three different perspectives, as shown in the title of each chapter – history, political economy, and corporate performance, on the evolution of China’s power system and its green efforts. The intention of incorporating these three different approaches is to situate the current challenges of green transition within a broader historical context of change within China’s politics, society, and economy, thereby providing a richer description of the development of China’s power system and its ongoing green energy transition and informing the possibilities and ways of rapid transitions.

Before the three main chapters, in this chapter, I have introduced the background of global efforts on tackling climate change and the role of energy supply systems in meeting the climate target and then elaborated on why China’s electricity industry is a unique and essential laboratory for examination of the sustainable path of the energy transition. By reviewing the existing transition studies, I have discussed the knowledge gaps in the history of China’s power system, the changing power relations in the process of green transition, and the empirical evidence of the system’s ongoing green transition on both local and firm scale. Based on these discussions, I have formulated research questions and introduced the overall research design and methods.

Chapter 2 elaborates on the conceptual framework of the thesis. It explains the rationale of dividing the thesis into three parts that focus on, respectively, the historical development of the socio-technical power system, a political-economy view on contemporary green transition, and a business perspective on transition. In doing so, it follows the systems approach to take into account the different components, processes, and actors involved in the system and the historical context in which the power system has developed at the national macro level. I argue that such a perspective is crucial for understanding and elaborating the complex dynamics between the different elements of the power system, identifying and depicting the drivers of changes in the power system, and understanding the path dependence of the Chinese power system and its current challenge and opportunities. The systems perspective says a great deal about forces driving and the developmental paths of the socio-technical system. Yet those insights are insufficient to understand the current green transition as the rapid transition requires addressing political and economic solutions. Thus, the critical political economy approach is integrated to unpack the power relations and explore the conditions under which an accelerated transition might happen. I draw insights from the neo-Gramscian perspective. The analytical lens shifts from the macro-level analysis of the national power system to the meso-level study focusing on the regional level analysis, which is further divided into three levels: provincial, municipal and village. Following is the micro-level analysis of the local business actors. The transition literature paid insufficient attention to the business, which is fundamentally and practically the key to the rapid transition. I analyse the state-owned and private generators in-depth, examining their green efforts and effects and interrogating their changing interests. Here, I stress that each of these three approaches to the subject involves a variety of scientific fields; and define the key concepts that construct the conceptual framework: energy sovereignty, system mass, historical bloc, and interest redistribution, which are derived from Hughes's concept of momentum. Aside from elaborating on the intricacies of each approach, I address major similarities and differences, as well as areas where they can complement each other.

Chapter 3 gives a historical overview of China's power system development. It uses the systematic method proposed by Thomas Hughes to unpack the system's evolution, aiming to get insights into the origin of the system and draw historical lessons about how, when, and why large-scale changes have taken place previously. In this chapter, China's energy and economic development is explained, the government's policies and institutional systems related to the power industry are reviewed to provide a general description of the political, economic and societal context of the electricity industry in China and a broader understanding of how the Chinese power system works in practice.

Chapter 4 presents a case study of a local electricity industry that has experienced a rapid uptake of green energy capacity. Based on it, it provides a political economy analysis, through a neo-Gramscian framework, of the process of local green transition regarding the relations of the different actors and driving forces of the changing relations.

Chapter 5 situates the long-lasting debate on the economic effects of being green in the context of the ongoing green transition. It combines a quantitative analysis of the relationship between financial performance (Return on Asset in this case) and environmental performance (the renewable intensity in this case) with a sample of Chinese electricity generation firms over the 2005-2017 period, with a qualitative investigation through interviewing participants in the industry. This chapter further refines the meaning of payoff by exploring the generators' changing perceptions of payoff over the past decade.

Chapter 6 concludes the thesis, first with an insight into the origin of China's power system and the actors and their changing roles in the evolution of the system, and then links the historical trajectory of the system's growth to the ongoing green transition summarising the driving forces behind the changes. Finally, the implications for researchers and policymakers are provided.

Chapter 2 Conceptual framework

2.1 Exploration of the research topic and the theories

This thesis is motivated by the desire to understand how the Chinese power system might shift to green. In recent decades, renewable energy technologies, especially wind and solar power, have diffused in the Chinese power system at an astonishingly rapid speed. On the other hand, the system is still heavily locked in coal-fired power. Though conflicts between the incumbent and the new player of green energies did exist, the rising of renewables seemed relatively peaceful compared with the progress in the West (Shen & Xie, 2018; also see findings in Chapter 4). It leads to several questions: How did this rapid development of wind and solar energy happen in China? What was the relationship between the renewable energy sector and the coal-fuelled power incumbent? How did their interactions influence the power system's transition to sustainability? Why conflicts, though they did exist, were not obvious in China? Eventually, how might a rapid transition happen?

To answer these questions, we need to figure out a fundamental question of what the Chinese power system is: Where does it come from? What is the structure of the system? What are the components of the power system, and how are they related to one another? What are its essential features? What makes it distinct from those of other countries? How does any particular feature affect and is affected by the historical period in which it moves? What are the continuance and major changes within the system? What are the mechanisms of the system's change? What are the principles of the system's development and historical change? To address these questions requires a historical scope of conception and full use of historical materials.

The entry point of the research is understanding the power system from the *systems perspective* developed by Thomas Hughes. He refers to the interconnectedness of the system and defines technological systems as integrated networks of multiple components, including technical, social, economic, political, and environmental factors. Such an approach recognises that technology and its development are closely connected to the overall surroundings. It emphasises that the external environment does not simply steer the progress of technology in one direction or another, but it also influences the specific way that ideas and processes are carried out; thus, it is inappropriate to view social factors, such as politics and economics, as just a backdrop, as they are actually integrated into the technology itself (Thomas P. Hughes, 1986).

The systems approach is a valuable and practical framework for understanding the complex and dynamic development of large-scale socio-technical systems. The idea of treating technological systems change in conjunction with changes in society and economy has inspired scholars, especially those in the socio-technical transitions, such as Rip and Kemp (1998) and Geels and Schot (2007). Applying the systems approach to studying the Chinese power system has several merits. First, it allows for a holistic view of China's power system by taking into account its multiple components, such as the political, economic, social, and technological systems, and how they interact and influence each other. The systems approach also emphasises the analysis of various stakeholders across the power system, including government agencies, power companies, consumers, financial institutions, and other interest groups. By considering various stakeholders and examining their interests and goals, one could gain a comprehensive understanding of the complex interactions and interdependencies within the system and a better understanding of the factors that shape the system's behaviour and outcomes. Second, it allows for an in-depth understanding of the dynamics of the power system. The systems approach considers the temporal dynamics of the power system, allowing for a better understanding of how it has evolved over time and how it may evolve in the future. This dynamic perspective allows a more nuanced understanding of the power system's historical development and current state. Third, the systems approach encourages an interdisciplinary approach to studying the power system, drawing on knowledge from various fields such as history, innovation, policy, political economy, and business. This enables me to analyse the Chinese power system from multiple perspectives and leads to a more nuanced understanding of the power system. In short, such an approach helps understand and elaborate the reciprocal impact of technology and society and identifies and depicts the drivers of changes in the power system.

Such a system conception does not imply a system is stable without conflict; instead, it is full of tensions. In his comprehensive examination of the Western socio-technical power systems, Hughes demonstrates how the growth and expansion of the system gained the attention and backing of capitalists, politicians, scientists, and entrepreneurs as it gained momentum (Thomas Parke Hughes, 1983). In this vein, various actors construct and hold systems together with different aims and interests. There is always the potential for their dissociation. Beneath the seamless web, there is often a fragile stability vulnerable to potentially hostile forces. Meanwhile, Hughes indicates how a new technological change encountered resistance and opposition from those with established interests as it expanded into more communities and became more deeply ingrained. However, his analysis places more emphasis on technological innovation and stabilisation and needs more investigations on the conflicts and the dynamic power relations between various actors (Callon, 1987; Mackenzie, 1987). Thus, in Chapter 4, I incorporate the critical political economy approach to unpack the tensions and power relations.

Wind and solar power development took place locally and was shaped by power relations and struggles. My search for theoretical insights to unpack the dynamic power relations that shape the local energy transition led me to draw insights from the neo-Gramscian perspective. It is a theoretical framework that draws on the work of Italian Marxist Antonio Gramsci to analyse power relations and social changes. This perspective emphasises the importance of understanding ways in which power relations are constructed and contested through a range of social, economic, and cultural processes. It is a useful framework for analysing how different actors create, contest, and challenge the hegemonic power relations and, therefore, identifying the forces that drive or hinder the transition. As applied in Chapter 4 outlines how and when assemblages of material, institutional and discursive power can be disrupted and unsettled to bring about regime change and create a window of opportunity for the deployment of renewables. Here, I stress that accounts of energy transitions drawing on neo-Gramscian scholarship provide a deeper understanding of the power relations and struggles that shape the socio-technical transitions. They do this by understanding the construction of hegemony and supportive shifts within the relations of forces at three levels – organisational, material, and discursive, which simultaneously reveals how actors experience the events and how the events change their experiences, expectations, views and their interests and power.

The very essences of both the systems approach and the neo-Gramscian perspective are the recognition of the interactions among players and the capture of the complex and non-linear nature of the transition process. In this vein, the motivations, perceptions, aims and interests of specific actors are central to my concerns. Governments across the world, from the national to the local level, declare climate emergencies and seek ways to address them quickly. However, businesses also need to play a crucial role in addressing the issue at the required speed and scale. Despite the question of speed and urgency having received great attention in general, 'business has a key, yet insufficiently analysed role' (Peter Newell, 2020, pp. 9-10). Therefore, I placed a greater emphasis on the part that businesses played and conducted a micro-level analysis of their practices, performances, and interests. Businesses are used to dealing with technological and cultural disruption and have to constantly adapt to threats from competitors, shifts in supply and demand, and changes in the landscape. Climate change adds to these challenges while also refining them. This requires either incremental reforms or a fundamental shift in how companies create value, generate profits, and operate to ensure their profit-making strategies align with sustainable goals. The fifth chapter concentrates on details of the investigation of corporate green efforts, their perceptions of payoff and adjustments of interests. I believe that observations and analysis at a more granular level provide insights into how specific firms are linked to the overall vision and progress of the national transition towards sustainability.

In conclusion, this thesis combines three different perspectives: the systems approach on the historical development of the socio-technical power system, the neo-Gramscian theory on the political-economy view on contemporary green transition, and the business perspective on corporate green efforts. These concepts are employed throughout the thesis to provide a cohesive understanding of the topics addressed.

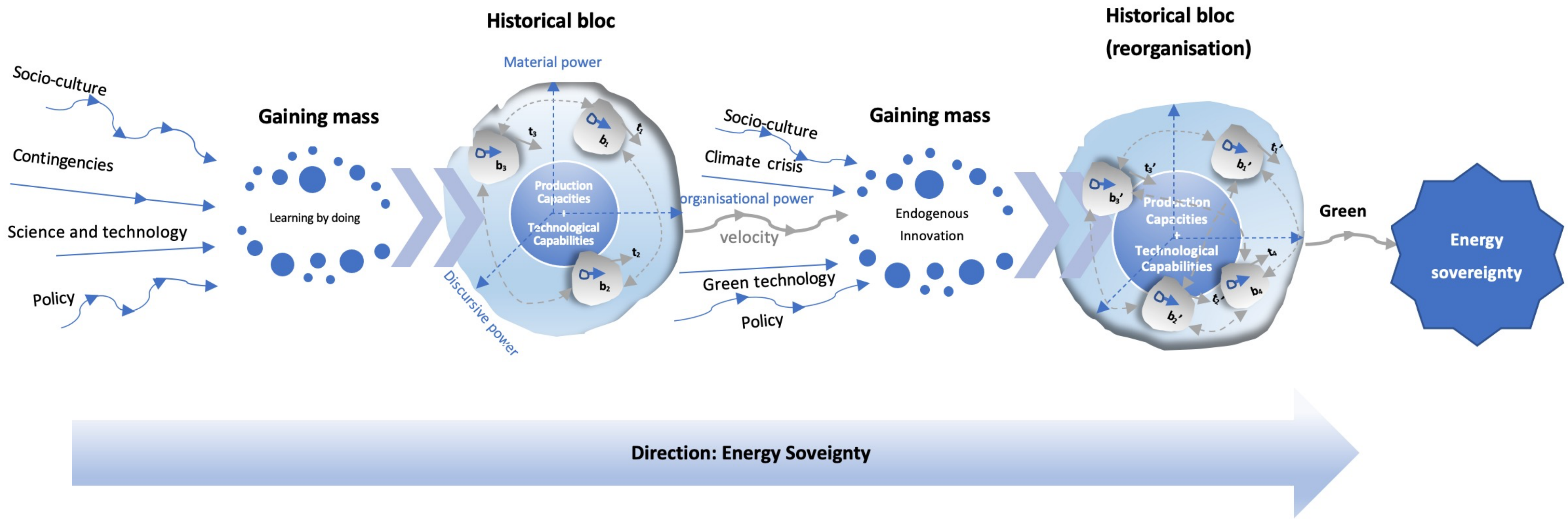

Figure 2-1 The conceptualisation of the momentum

In the following subsection, I propose a conceptual framework that builds on Hughes' conception of *momentum* (Figure 2-1). I will explain how such a concept is applied and further developed by incorporating ideas from other perspectives to create the conceptual framework to study the evolution of the Chinese power system and its green transition, as well as the key concepts that compose my thesis.

2.2 Momentum: direction, mass, and velocity

According to Hughes's systems approach, momentum is a product of three key elements: mass, velocity, and direction. It refers to the dynamics of a technological system and the various forces that drive it forward and move in a particular direction. This concept is helpful in building a conceptual framework for studying the Chinese power system's evolution by analysing the three elements of the system. Direction refers to the overall trajectory of the system. Mass refers to the size and complexity of the system. Velocity refers to the rate of change in the system.

Applying this framework to studying the Chinese power system, I suggest first identifying the direction of the system's development and analysing the forces that drive the system in this particular direction; then followed by an assessment of the mass of the system and the mechanism through which the system accumulates the mass; finally, analysing the velocity of change which aims to explore the issues of rapid transition. Here I argue that acceleration depends on the mass and the resultant force, following the conceptualisation of Newton's Second Law of Motion that the sum of forces equals the mass times the acceleration of the object. Unpacking the force is particularly crucial to understand acceleration, which can be done by investigating the interest groups, the interactions of the actors, power relations and struggles. Four concepts emerged accordingly: energy sovereignty, system mass, historical bloc, and interest redistribution; the former two correspond to concerns of direction and mass, and the latter two address accelerated transition.

2.2.1 Energy sovereignty: direction

I agree with Hughes (1983) that 'A system usually has a direction, or goals. The definition of goals is more important for a young system than for an old one, in which momentum provides an inertia of directed motion' (p. 15). When studying the Chinese power system, a late developer, it is especially crucial to identify and then bear in mind its direction. I argue that the clear and consistent direction of the Chinese power system is the reason behind its rapid and sustained growth, and such direction also explains why China did not experience evident conflict between the fossil fuel industry and the renewables as what we often see from the West and led to the peaceful rise of renewable energies. Energy sovereignty has been the direction from the outset.

Energy sovereignty is a concept that recognises the right of a nation, region, or community to develop, control, and govern its own energy sources and infrastructures, without interference from outside forces (Laldjebaev, Sovacool, & Kassam, 2015; Schelly et al., 2020). It is often seen as a key aspect of national sovereignty and self-determination, as it enables countries to develop their own energy system in a way that is consistent with their social, economic, and environmental goals (Schelly et al., 2020; Thaler & Hofmann, 2022). It is also often associated with efforts to promote sustainable and equitable energy systems that prioritise the needs of local communities and the environment. Broto (2017) distinguishes energy security from energy sovereignty. She suggests that energy security emphasises the availability of energy resources at the national level. While energy sovereignty highlights local people's needs, interests, and control of energy, allowing communities to use resources that are both affordable and sustainable and resources that promote economic and environmental justice. Laldjebaev et al. (2015) treat energy security as the goal and energy sovereignty as the process of reaching the goal of energy security. They stress that energy sovereignty is 'a process of complex decision making that is influenced by many factors including cultural values, financial wherewithal, technological capability, and ecological foundation of households' (p. 107). On all accounts, energy sovereignty embraces the ideas of self-sufficiency and independence at the national level and locates 'sovereignty' in people and their institutions.

The goal of achieving energy sovereignty is becoming increasingly prominent in energy politics (Timmermann & Noboa, 2022). In this thesis, I define energy sovereignty as achieving a self-reliant and sufficient power system which is simultaneously affordable and sustainable. This goal stemmed from the history of invasion and aggression in modern China and the imprint of ‘Communism is Soviet power plus the electrification of the whole country’ (Lenin, 22 December 1920) (see Chapter 3 in detail).

In the century since 1840, China suffered from constant war. The invaders brought the electricity industry to China for their own sake, exploiting the resources without technology transfer. As the invaders retreated in the end, they took away or destroyed the equipment and infrastructure, plus the break-up with the Soviets in the 1950s made the Chinese identify self-sufficiency as key to national security. As an industrial latecomer, the country’s economic growth depended on reliable energy supplies, and the leadership staked its legitimacy on the economic miracle. Providing secure energy supplies at affordable prices is vital to the Communist party to secure its political stability and the country’s economic security and stability. When air pollution from burning fossil fuels outbroke in the early 2000s, people’s anger towards the environmental issues jeopardised the political regime. The government recognised the importance of sustainability, which not only provides solutions to the issues in economic growth and political regime but also indicates a pathway to achieve both energy and ecological security. Thus, China has set ambitious targets for the expansion of renewable energy sources and is investing heavily in developing green technologies, striving to shift towards a more sustainable energy system.

Meanwhile, the ambition of electrifying the whole country, leaving no household behind, since the first generation of leadership of the People’s Republic of China, has pushed the rural electrification project forward. Renewable energy projects have helped China accomplish the rural electrification project by the end of 2015 by providing cost-effective, reliable, and sustainable energy solutions to rural communities. Distributed renewable energy systems, such as rooftop solar panels and micro-hydro projects, have helped to bring electricity to remote areas to meet the energy needs of rural communities.

Correspondingly, off-grid renewable energy systems, such as solar home systems and mini-grids, have been installed to provide electricity to rural households that are too far away from the state grid or too expensive to connect to, offering a cost-effective and reliable alternative.

In short, energy sovereignty has been the direction of China's power system since its early-stage development. The system's development and the ongoing green transition aim to enhance its independency, reliability, affordability, accessibility, and sustainability.

2.2.2 System mass: 'learning by doing'

Hughes defined mass as an amalgam of physical artefacts, professionals, businesses, government agencies, professional societies, educational institutions, and other organisations that shape and are shaped by the technical core of the system, 'a system with such mass usually has a perceptible rate of growth or velocity' adding to the momentum (Thomas Parke Hughes, 1983, p. 15). As the late developer, how could the Chinese power system raise its mass and grow to become the world's largest? Perhaps the most important lesson we could draw from the history of the Chinese power system, as seen in Chapter 3, is through 'learning by doing', which has two main dimensions: technological learning and policy learning.

Bell and Pavitt (1993) referred to technological learning (or technological accumulation) as the accumulation of technological capabilities. By 'technological capability', they mean the skills, knowledge and institutions needed to generate and manage technological change. A parallel concept is 'production capacity', referring to the equipment, capital goods, and labour skills required to produce industrial goods with a given technology. They concluded that the central feature of the technological accumulation in the early stages of the development of today's developed countries was the 'the parallel and interacting accumulation of production capacity and technological capabilities' (Bell & Pavitt, 1993, p. 198).

In its early development, China, as the industrial latecomer, recognised that technological capability has to build on the industrial production capacity. It relied on the international diffusion of technology and the adoption of established technologies. Various approaches have been taken to acquire external technologies, including purchasing equipment and production lines, technological licensing, foreign direct investment (FDI), and recruiting talented persons, both Chinese and foreigners. On the other hand, China realised that being adopters and users of diffusing technology, they need to possess the particular kinds of knowledge and skill required to play the technology. To process the requisite skills, they need learning by doing, a dynamic combination of the artefact and the immediate human activities that support the use, adjustment, and advancement of the relevant technology. Plus the pursuit of energy sovereignty, therefore, in the post-war era starting from the 1950s to the 1990s, China adopted the 'self-sufficient approach' as the development strategy, stressing 'with the capacity of capital goods production…the economy would then be able to reproduce itself based on the domestic provision of technology' (Gu, 2001, p. 204). Later on, since the 2000s, China has modified the strategy to 'endogenous innovation', emphasising 'innovation-driven growth and learning-based development' (Gu & Lundvall, 2016, p. 430). The Chinese experience proves that successful technology transfer requires the associated transfer of actual artefact as well as the production processes, the users' skills base, work practices and other supporting sources (Fleck, 2008).

The other central feature of the Chinese development strategy is 'experimentation-based policy learning', a pragmatic and practical approach China adopts in shaping industrial and technology policy as well as climate-relevant policies (Gu & Lundvall, 2006; see also Chapter 4). This feature makes China a prime example of an authoritarian government surviving indefinitely despite rapid economic and social development. Lundvall (1999) explains the collapse of the planned economies in the Soviet Union and Eastern Europe as the result of 'the learning and innovation process came to a standstill' (p. 25) resulting from the centralisation of research and development activities rather than a poor utilisation of existing resources resulting from too little market. The reforms in the 1980s exemplify pragmatic institutional reforms in which China shifted the centrally planned policy system following the Soviet model towards decentralisation, privatisation and openness. Local levels of administration possess a substantial command of policymaking. Entrepreneurs are allowed to integrate into the communist party, making them 'red capitalists' (Dickson, 2008). Yueh (2019) comments that the emergence of entrepreneurs within a communist system may not be what Marx could have predicted. Thus, we can see that China is open to the necessity of modification. In building the Chinese power system, as shown in Chapter 3, each progress was made by examining the information and experience gained from the preceding step.

In short, China's experience says a great deal about the importance of learning from the advanced economy and, more importantly, learning from the ongoing experimentation within the system.

2.2.3 Historical bloc

As discussed at the beginning of this chapter, the socio-technical system is a function of the interaction of heterogenous elements (Callon, 1987), and its stability is 'a frequently precarious achievement in the face of potentially hostile forces' (Mackenzie, 1987, p. 197). Thus, the system never lacks conflicts. The system's green transition process is full of recursive interactions and multi-dimensional struggles. As applied in Chapter 4, the concept of the historical bloc is helpful in unpacking the complex relations between heterogeneous actors.

The historical bloc encompasses the apparatuses of government, private institutions and organisations, and the mass public; and refers to a combination of social, economic, and political forces that come together to form a dominant hegemony. The stable historical bloc needs both the coercive side of political power need and consent from the public (Gramsci, Hoare, & Nowell-Smith, 1971). Such an approach offers a way of understanding both continuity and change. It pays attention to the organisational, economic, and ideological pillars of power to investigate the assemblage of political, economic, and discursive struggles in the green energy transition. Analysing the three sets of forces relations can bring light to the complexity of the processes of coercion, consent, and resistance involved in the transition and illustrate the process of coalition building, conflict, and accommodation that drive systematic change.

The neo-Gramscian concept of the historical bloc is based on the idea that a combination of forces determines the existing power structures in a given society or system and that to bring about radical changes, the existing power structures must be challenged and transformed. However, such an idea is dubious regarding the Chinese energy transition, where the existing power structure does not necessarily be challenged and changed. In China, the incumbent fossil-fuel regime did not water down sustainability ambitions and hold fast to the existing trajectories; instead, the regime actors are interested in building and operating in the renewable sector. The niche actors, rather than striving to challenge and destroy the regime, prefer to work on the niche and are willing to cooperate and build an alliance with the regime. Both sides are open to change.

This harmonic dissonance is a unique characteristic of China. As indicated in the previous subsection, China is a country where strong authoritarianism coexists with a high degree of decentralisation. On the one hand, it is a highly top-down and hierarchical society that sticks to a stodgy economy with rigid five-year plans prepared by committees of technocrats; on the other hand, it is a Darwinian capitalist marketplace with the world’s most ruthless and innovative entrepreneurs. Such a harmonic dissonance is evident in the electricity industry, where a centralised power system dominated by fossil fuels coexists with rapid-developed distributed power systems of renewable energy, and the state-owned electric enterprises (SOEs) coexist peacefully with various private generators. The government and the centrally-controlled SOEs remain to hold the majority control power, while private generators are indispensable in driving and stimulating the energy transition, especially at the local level.

Nevertheless, the concept of the historical bloc is a useful analytical tool to unpack the power relations to understand how forces interact and shape and influence the direction and the speed of the sustainability transition. The conclusion of Chapter 4 indicates that the successful diffusion of green technology depends on physical and technological conditions and the collaboration of various actors and requires consent from government, business and civil society that calls for a clever strategy, plus serendipity.

2.2.4 Interest-redistribution

Corporate capitalism is widely acknowledged as the major driver of climate change (Klein, 2014). On the other hand, business is also the key to combating global warming. The big electric firms are ‘street-level bureaucrats’ who are providers of public benefits and have substantial discretion in the execution of their work (Lipsky, 2010, pp. 3-4). Street-level bureaucrats perceive themselves as doing their utmost within the norms of the system in which they work, considering the resources they have been given and the circumstance they encounter. Thus, they develop a sense of self-awareness that they are doing their best within the given circumstances (Lipsky, 2022). This notion is a good entry point to understand the Chinese generators, yet sufficient given the distinct features of the SOEs and private firms in China. Their dynamic role and interests in the dynamic transition process are poorly recognised, but it is critical to examine the role of businesses in the green transition and see what real change has happened.

SOEs have traditionally and still dominated the electricity industry in China. However, as the country has sought to shift towards a cleaner and more sustainable energy mix, private generators have emerged as important players in the renewable energy sector. SOEs and private actors have played different roles and had varying interests in the industry. As the green transition proceeds, so do their interests because of their changing perceptions of ‘payoff’ (see Chapter 5).

SOEs are widely recognised as incumbent actors. They can exercise material and political power and have privileged access to finance and key arenas of decision-making; however, it does not mean they do not have to compete with diverse business interests, especially those at the local level. The local SOEs need to ensure a reliable electricity supply, respond to the government targets for reducing greenhouse gas emissions and increasing the share of renewable energy in the local energy mix, and, at the same time, meet the financial targets set by the headquarters.

Private generators, on the other hand, have been attracted to the renewable energy sector as a growth opportunity and actively invested in renewable energy projects, leveraging their agility and flexibility to adapt to changing market conditions and regulatory frameworks and, eventually, expanding their market shares.

Overall, the redistribution of interests between SOEs and private generators in the green transition in China has been shaped by a range of factors, including government policies, market dynamics, and technological innovation. While SOEs continue to play a dominant role in the electricity industry, private firms have been able to carve out a niche in the renewable energy sector. The findings in Chapter 5 show that SOEs continue to enjoy political privilege but no longer prioritise the pursuit of growth and sheer size; instead, they strive for profitability. Their pursuit of profits, coincidentally, drives an accelerated development of the renewable energy sector, proving green is not just a goal but a way to achieve sustainable growth. In contrast, private actors have shifted their pursuit from profits to political advancement and are devoted to enhancing technology and innovation capabilities.

2.3 Reflections

As discussed in the previous section, the proposed conceptual framework originates in crossovers between three different theories. These various theories centre around the process and progression that occurs over time. They are considered historical theories, seeking to explain current conditions by examining past events and developments. The systems approach recognises the importance of historical context and the influence of historical events and developments on the current system. The search for the corporate green efforts and their changing perceptions of payoff in the context of green transition opts for a longitudinal research design paying attention to how the country's sustainability transition progress affects the business actors' interests and vice versa.

Concerning the political economy perspective, one of its defining characteristics is the historical foundation (O'Hara, 2009). The grand political economists, such as Karl Marx and Joseph Schumpeter, relied on history to assist in their comprehension of evolutionary processes; and some recent scholars, especially those concentrated on transition studies such as Peter Newell and Simms (2020), also embedded history in their political economy approaches. History provides a corpus of knowledge concerning drivers and phases of evolution, life cycles, changing habits and technologies, and path-dependent patterns. Without it, the political economy would be ‘a mere formality, lacking in operational, social and organisational content’ (O'Hara, 2009, p. 224). It is especially the case with the energy system, which is subject to strong and long-lived path dependence because of industrialisation. The fossil-fuel-backed industrialisation creates technological, infrastructural, institutional, and behavioural lock-ins and, ultimately, path dependence. To understand the lock-ins and path dependence, identify implications, and formulate strategies to deal with them, we need to situate it within the framework of past phases of development and change.

Notably, both the systems and neo-Gramscian approaches see technology as a product of society and a reflection of social relations. They argue that technology is not developed in a vacuum but is shaped by the social, economic, and political context in which it emerges. Its evolution proceeds not solely based on scientific or technical considerations but is also influenced by social, economic, and political factors.

The three perspectives are all concerned with understanding the dynamics and interconnectedness of the complex socio-technical systems and the factors that shape them. They all consider how different actors interact with each other and how their interactions shape the system. However, they differ in their focus and approach. The systems approach emphasises the importance of understanding a system's internal structure and dynamics; the neo-Gramscian approach places greater emphasis on the power relations of various actors in shaping the direction and pace of change; while the business perspective highlights the varying interests of individual actors. The systems approach considers the temporal dynamics of the system, while the neo-Gramscian method focuses more on the meso- and micro-level dynamics, and the business analysis focuses on tracking the changes in individual actors' interests over time. By combining them, it is able to concentrate on alignments between processes at multiple levels with different temporalities and, therefore, gain a deeper understanding of the complex interplay of components and power relationships and the forces of changes shaping the evolution of the Chinese electricity system and its transition. This could further provide insights into the key factors driving the transition and the obstacles that must be overcome to accelerate the transition.

Additionally, these three perspectives represent three analytical scales. The systems approach focuses on the entire system. In contrast, the neo-Gramscian approach examines the interactions between a smaller group of actors, and the business perspective locates the analysis on the corporations. Accordingly, the empirical investigation was conducted at three spatial scales: the macro-scale research relates to the system's national-scale development and within the global context; the meso-scale study focuses on the local energy transition concerning the dynamic interactions among various actors in city, village, and community; and the micro-scale transition zooming in on the business actors.

After reviewing relevant insights, strengths and weaknesses in different theories, I conclude that neither one can be straightforwardly applied to studying the system and transitions; however, each has strengths and weaknesses, focusing on particular issues rather than others. The proposed conceptual framework attempts to combine the strengths of one approach to address weaknesses in the other.

Chapter 3 Historical Overview of China's Power Sector

3.1 Introduction

When the People's Republic of China (PRC) was founded in 1949, its total electricity generation capacity was less than 2 gigawatts (GW), of which only 3.63 megawatts (MW) were available for the country's massive countryside (Peng & Pan, 2006). Nowadays, China's power sector is the largest globally, with 1,777 GW of total capacity (end of 2017), accounting for around a quarter of global power generation (IEA, 2018). China achieved a remarkable accomplishment of complete rural electrification at the end of 2015 (NEA, December 2015), lifting hundreds of millions of citizens out of poverty. The power sector's remarkable growth has provided a crucial basis for China's exceptionally rapid economic growth over the past decades. However, these achievements have created an enormous carbon footprint. With abundant coal supplies, China's power system consumed nearly half of the world's coal, generating 11.1 per cent of global carbon dioxide emissions as well as around 1.16 million tonnes (Mt) of sulphur dioxide and 1.11 Mt of nitrous oxides (IEA, 2018). The power sector has become the decisive area of efforts to address the pressing domestic air pollution and tackle global climate change. Meanwhile, slower demand growth in the past two decades has led to a substantial overcapacity. To address these challenges, China has embarked on a series of reforms in the power sector to improve economic efficiency, reduce coal reliance, and shift towards a green energy system.

The evolution and success of China's electricity system have caught several scholars' interest. For instance, in their edited volume, L. Brandt and Rawski (2019) provide rich information on China's electricity industry policy, regulation, and innovation. Lewis (2013b) tells a story of China's technology transfer policy in her book on China's wind sector's rise. Gallagher (2014) offers a rich analysis of the factors influencing the international transfer of clean energy technology in and out of China in her book on China's leading solar photovoltaic sector. Most of the research explores the Chinese power system of the 21st century, since when the industry has experienced astonishing growth under the two rounds of market-oriented sector reform. Relatively little research has been carried out on the pre-reform period. China’s first electric light was lit in the Shanghai Public Concession in 1879, almost in sync with the beginnings of electric power development history throughout the industrialised world (D. Li, 1983, p. 4). Then in 1882, British businessmen founded China's first electric utility company in Shanghai, writing the first page in the history of the development of China's power industry since then (ibid). In the next 100 years, the development of China's power system has undergone radical changes along with China's transition from a semi-feudal and semi-colonial country to the founding of the People’s Republic of China and then to the Economic Reform and Opening Up, from entirely relying on technology imports to independent research and development. So far, however, there is a relative paucity of studies investigating the origins of the Chinese electricity system and the factors that drove the growth and change of the system throughout different phases of the system development. This chapter attempts to address that research gap, in the process laying the ground for understanding the key characteristics of, and actors in, the Chinese energy regime. This understanding is crucial to an assessment of potential pathways to sustainable energy transition.

The primary aim of this chapter is to trace the history of the Chinese power system. Specifically, this chapter applies Thomas Hughes’s systems approach to conduct the interrogation. In his seminal work, *Networks of Power*, Thomas Parke Hughes (1983) treats electric networks as systems as they developed in the United States, the United Kingdom, and Germany between 1880 and 1930 as systems, ‘coherent structures comprised of interacting, interconnected components’ (p. ix) including ‘technical matters, scientific laws, economic principles, political forces, and social concerns’ (p. 1). He views technological change as evolving in response to social, political, and economic circumstances. He employs useful conceptual tools for describing four phases of development in electrification. In the first stage, inventor-entrepreneurs establish the groundwork for the new system. Then, technology transfer happens to meet local conditions. In the phase of system growth, the system encounters ‘reverse salients’, which are components in need of attention because they ‘have fallen behind or are out of phase with the others’ (Thomas Parke Hughes, 1987, p. 73). The correction of reverse salients will, for instance, enhance systemic efficiency or create a new form of organisation; and, if those that cannot be corrected within the existing systems, attention to reverse salients may bring the birth of a new and competing system, for example, 'the War of the Currents'.[3] The final stage gains substantial momentum providing 'an inertia of directed motion' (Thomas Parke Hughes, 1983, p. 15); however, 'contingencies [such as wars or economic or social crises] push systems in new directions' (p. 16).

Applying the systems approach to studying the Chinese power system has several merits. First, it allows for a holistic view of China's power system by taking into account its multiple components, such as the political, economic, social, and technological systems, and how they interact and influence each other. The systems approach also emphasises the analysis of various stakeholders across the power system, including government agencies, power companies, consumers, financial institutions, and other interest groups. By considering various stakeholders and examining their interests and goals, one could gain a comprehensive understanding of the complex interactions and interdependencies within the system and a better understanding of the factors that shape the system's behaviour and outcomes. Such a perspective can, furthermore, provides an explanation of complex power structures and relationships that exist within China's power system. This can help to shed light on how decisions and policies are made, who holds power, and how power is exercised. Another advantage of the systems approach is that it allows for an in-depth understanding of the dynamics of the power system. It considers the temporal dynamics of the power system, allowing for a better understanding of how it has evolved over time and how it may evolve in the future. This dynamic perspective allows for a more nuanced understanding of the historical development of China's power system and its current state. At last, the systems approach encourages an interdisciplinary approach to studying the power system that draws on knowledge from various fields such as history, innovation, policy, political economy, and business. This enables me to analyse the Chinese power system from multiple perspectives and leads to a more nuanced understanding of the power system. In short, such an approach helps understand and elaborate

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[3] The 'War of Current' is an epic race to standardise America's electrical system. In the late 1880s and early 1890s. Thomas Edison – a firm supporter of the direct current (DC) system, and Nikola Tesla and George Westinghouse – promoters of the alternating current (AC) system, battled over which electricity system was superior and would become standard. Ultimately, AC became dominant in America's power industry. (Gomez-Rejon, 2017; Nix, 2019; Waxman, 2019)

the reciprocal impact of technology and society and identifies and depicts the drivers of changes in the power system.

This chapter will integrate the technical, political, institutional, professional, social, and economic factors in analysing factors that shaped the industry's growth. In the pages that follow, the following questions will be addressed: Who built China's power system? Who were most active and critical decision-makers in different phases of history? What were the causes of the growth of the power system? How did China's power system acquire momentum and develop its technological style?

This chapter mainly took reference to materials published in Chinese: archives assembled by the China Electric Power Yearbook Council; historical materials compiled by individuals, for example, D. Li (1983) recorded the historical data of China's electricity industry before 1949, which was the first general history of the industry; the oral history, diaries and memoirs of the Chinese electrical engineers narrated the history of the Chinese power sector, the most representative ones are Yun (2000a, 2000b) recounted his experience as one of the earliest participants and scholars in China's electricity industry before 1953, P. Li (2005, 2014) recorded the development and reform of the sector between 1979 and 2005 in detail, and Liu (2015) recalled his 18-year participation in the power sector reform and described the front and back of the reform; the *Selected Works of Mao Zedong* indirectly recorded China's technology development in Mao's time; local chronicles and a considerable amount of government documents. The remaining part of the chapter is organised around the sequential sub-periods of the 1880s-1953, 1953-1978, 1978-2002, 2002-2015, and 2015 to the present. The chosen chronological phases reflect the phases of the system evolution, with the 1880s-1953 section concentrating on the origin of China's power system; that on 1953-1978 exploring the system growth; 1978-2002 examining how the system gained momentum; 2002-2015 tracing the development of the system equipped with the Chinese style. The final section investigates the latest electric reform with a focus on green transition. The lack of green focus in earlier periods is because the priorities and foremost concerns of earlier stages of the system's development were abundant and reliable electricity supply to support the high levels of economic growth (Andrews-Speed & Zhang, 2019; Baron et al., 2012; IEA, 2006, 2018).

3.2 The origin of China's power system (1880s-1953)

The emergence of the electric lighting system and the public utility in China originated from the concessions occupied by the imperialist powers, railways and mines controlled by them,[4] and the Qing government supplying electricity to the imperial palace.[5] After the Eight-Nation Allied Forces invaded China in 1900, electric facilities were quickly established in concessions nationwide and controlled by foreign merchants. To resist the imperialist invaders from monopolising China's power market, some Chinese businessmen invested in and developed China's own national power industry. However, they depended entirely on technology imports and had no management experience. Most of the power plants were on a small scale and bankrupted eventually, leaving 18 big generators (D. Li, 1983, pp. 7-9). By the overthrow of the Qing dynasty in 1911, the country's total installed power generation capacity was 27 MW, of which 12 MW was operated by the national capital, which only electrified a few cities and concessions (CEPYC, 2002, p. 4).

3.2.1 Wars

The outbreak of the First World War brought opportunities for the growth of China's national power generation industry. Since the invaders had shifted their focus to the battlefield, the domestic industrialists and merchants had the chance to participate in electrification. In 1929, the National Government of the Republic of China (1925-1948) established the Construction Committee, which was in charge of the electricity industry, formulated various electricity laws and regulations, and issued voltage and frequency standards. In 1935, the Nationalist Government (also called Kuomintang) set up the Resource Committee to

[4] In April 1882, Robert W. Little, the former chairman of the Shanghai Municipal Council, established Shanghai Electric Co. He introduced the electric lighting technology from the American Brush Company of Cleveland and invested in the British concession in Shanghai. At the end of 1882, the first power plant in China was built with a total generation capacity of 11.93 KW. (Y. Yang, 2013)

[5] In April 1888, the Qing government built a 15kw generator in Beijing to supply electricity to the Qing imperial palace. In the following 20 years, the court installed two more generators with a total capacity of less than 50kw only for the usage of the royal palace. (CEPYC, 2002, p. 10)

investigate hydropower and prepare thermal and hydropower plants. By the end of 1936, there were 461 power plants nationwide with an installed capacity of 631.2 MW, of which nearly 60 per cent came from power plants invested by the national bourgeoisie and the National Government (CEPYC, 2002, p. 15).

After the Japanese invasion of Manchuria in 1931, all the electric facilities, amounting to 230 MW (ibid), were overrun by Japan. Manchuria is a vast and affluent area of China associated with three provinces in northeastern China. It is the centre of China's heavy industry and has abundant natural resources. The Japanese set Manchuria as an industrial and military base for Japan's expansion into Asia. In 1934, Japan established the Manchuria Electric Power Joint Stock Company (MEP) in Changchun to forcibly operate the entire electricity industry in the northeast. At the same time, it formulated a five-year plan (1937-1941) to vigorously build power plants throughout the region (Manshihui, 1988, p. 135). In 1937, the Second Sino-Japanese War broke out. Except for the concession areas, the electric equipment in most provinces of the country was looted by Japan, and the country's electricity industry was under military control within a year. In October, Japan started to build large-scale hydropower stations in the northeast, among which Fengman (522.5 MW) (CEPYC, 2002, p. 24) and Shuifeng (7*100 MW) (Manshihui, 1988, pp. 153-154) were the world's largest units at that time (Manshihui, 1988, p. 148).[6] MEP started power grid construction in 1935 and built transmission lines across the northeast, including China's first 220-kilovolt high-voltage line. By 1942, the northeastern power grid was initially formed. As of the end of the Second Sino-Japanese War, the total capacity of power generation equipment in Manchuria had reached 1,779 MW (CEPYC, 2002, p. 15). However, the electricity was rarely used by civilians, and most of it was sent to factories built by Japan in northeastern China to plunder mineral resources and

[6] Northeastern China has abundant hydropower resources. In its five-year electric power industry plan, MEP set the principle of power construction to be 'primarily hydropower and supplemented by thermal power' (Manshihui, 1988, pp. 135-136). In 1937, three large and medium-sized hydroelectric power stations of Shuifeng, Jingbo Lake, and Fengman were built simultaneously, used as power centres of the southern, central and eastern Manchuria. They were on-grid in 1941, 1942, and 1943. By 1945, Fengman power station still had four generators (a total of 280 MW) to be installed. However, after the war, the Soviet army plundered about 410 MW of electric equipment (D. Li, 1983, pp. 123-124). Due to the importance of the Fengman hydropower station, PRC's first Five-Year Plan, starting in 1953, listed the reconstruction of Fengman station as a crucial project which was on-grid by 1960 (C. Chen, 2015, pp. 95-96).

supply Japan's steel, coal, and other heavy industries (Manshihui, 1988, pp. 157-170).

As Japanese troops moved south to invade China's territory further, Japan successively established seven regional power corporations in northern, central and eastern China to fully control the utilities in these regions (D. Li, 1983, pp. 92-112). After the outbreak of the Pacific War in 1941, Japan took over the utilities run by the British and Belgians in Beijing and Tianjin. As the Kuomintang fled to Chongqing in 1938, part of the electric equipment was moved to the southwest. Its Central Machinery Factory, the base for wartime military production, the reservoir of talent, and the cradle of the nation's technological innovation (Kong, 1982, pp. 72-75), was relocated to Kunming (Yun, 2000b, pp. 202-203). Although the total installed electricity capacity increased slightly in the Kuomintang-ruled areas from 35.5 MW in 1938 to 75.6 MW in 1945 (D. Li, 1983, p. 24), the electricity branch of the Central Machinery Factory had attracted and trained a large number of electrical engineers, who became the pioneers of China's electricity industry. This point will be discussed further in the subsequent subsection.

After the defeat of Japan in 1945, Soviet troops plundered Manchuria confiscating the industrial machinery in this region. Approximately 973 MW of the power generation facilities in the northeast were dismantled by the Soviets, leaving only 600 MW of equipment, and the rest was damaged during the war (D. Li, 1983, pp. 120-123). Likewise, most power plants in other parts of China were also destroyed during the Japanese retreat. Kuomintang took over the remaining electric equipment, approximately 1,455 MW (excluding Taiwan), of which the northeast region accounted for 60 per cent (CEPYC, 2002, p. 16). During the Second Civil War, from 1945 to 1949, China's power industry was at a standstill.

3.2.2 Enlightenment

War brought electric facilities to China and was the chief driver of the industry's growth in the formative years of the history of China's electric supply system. However, it is scientists and engineers who build the power system. Who were the scientists and engineers that created China's power system in the first place?

Before answering this question, we need to push history back further to the development of electrical science in China.

While the Western countries were invigorated by the industrial revolution in the 18th century, late imperial China's government adopted a Closed-Door Policy toward the Western world. Since 1757, the Qing government banned foreign trade, products, learning, and technologies. The feudal rulers' rejection of the achievement of other nations in science and technology reinforced China's gap with other countries and weakened China. Not until the defeat of the Opium War in the 1860s did some Qing courtiers and officials recognise the need to open up to advanced ideas and technologies to strengthen China. Scholar-generals such as Zeng Guofan (1811-1872), Li Hongzhang (1823-1902) and Zuo Zongtang (1812-1985) initiated Westernisation Movement (also known as the Self-Strengthening Movement), aiming to graft the Western science and technology onto Chinese institutions. From the 1860s through the 1890s, under the direction of leaders who had a pioneering spirit in science and technology, modern institutions were established to study Western science and languages, and basic industries were developed according to the Western model. By the end of the 19th century, the national bourgeoisie achieved initial development, which provided an economic foundation for the establishment of the national electricity industry.

In the mid-1890s, Peiyang University and Nanyang Public College were established as the earliest public universities in modern China. These two universities, located in Shanghai and Tianjin, have successfully set up sciences, management, civil engineering, and mechanical engineering schools to train a group of technical and management professionals for China's electrical industry. In 1898, the Qing emperor announced the reform (known as Hundred Days Reform) and advocated learning from the West, reforming the political and educational systems, and encouraging private enterprises. This reform was a crucial enlightenment movement in modern Chinese history. Although the reform only lasted 103 days and ended in failure, all the new policies except for the Imperial University of Peking (the predecessor of Peking University) were abolished. The establishment of the Imperial University of Peking promoted China's ideological emancipation movement, where Western literature and sciences were taught, students were sent abroad to learn Western sciences and technology, and scientific works and inventions were rewarded.

After the collapse of the Qing dynasty and the founding of the Provisional Government of the Republic of China in 1912, more public universities with sciences and engineering departments were established. Then the students applied to study abroad and practised in foreign companies. In the *Oral History of Yun Zhen*, Yun, after he graduated from the electrical engineering department of Nanyang Public College in the 1920s, went to the United States for postgraduate study. He also interned at Westinghouse Electric Corporation as an electrical tester, where he conducted practices and daily operations (Yun, 2000b, pp. 190-191). He then worked in Dwight P. Robinson Engineering Co., where he learned the procedures for building and running a power plant, from designing to managing the power plant (Yun, 2000b, p. 192). Along with other Chinese students who went to the United States to study, he established a good rapport with American electrical companies. After the severance of diplomatic relations with Germany in 1941, which China once heavily relied on to import technology and equipment,[7] the United States became China's primary counterparty on technology transfer in the 1930s and 1940s (Yun, 2000b, pp. 199-205).

In 1927, the Nationalist government established Academia Sinica, an official central organisational of scientific research composed of the country's leading scientists (Zuoyue Wang, 2015). In the mid-1930s, the Chinese society of electrical engineers was established, composed of engineers who returned from abroad. It was then incorporated into the Resource Committee, responsible for cultivating electrical technicians and management personnel (CEPYC, 2002, p. 150). Under the leadership of such engineers, the Resource Committee has a theory of 'industrialised China', putting 'talent reserve' as the priority and adopting a policy of equal pay for technical and management personnel (F. Wu,

[7] In 1935, the Resource Committee of the Nationalist Government formulated a five-year plan for heavy industry. They went to Germany to purchase arms and ordnance equipment, as well as industrial equipment. Before the outbreak of the Second Sino-Japanese War, the Resource Committee signed equipment purchase and technology transfer contracts with the German Siemens Halske Co. and A.E.G. for the government's electric construction. Before 1940, the advanced equipment in Kuomintang's Central Machinery Factory was imported from the United States, Germany, the United Kingdom., and Switzerland, among which the former two were the main ones. (Kong, 1982, p. 73; Yun, 2000b, pp. 199-206)

1988; Yun, 2000b, p. 205). They called for only focusing on the pursuit of excellence in design and quality and ignored the political movements, which ensured that engineers could concentrate on technology improvement and production (Z. Wu, 1988, pp. 103-113). In 1942, the Resource Committee strengthened its technical cooperation with the United States and set up an office in New York. The two largest technology import contracts signed by the Resource Committee were made with Westinghouse Electric Corporation and S. Morgan Smith Co.(Yun, 1988, p. 155). They agreed with the Central Machinery Factory to recommend outstanding personnel to the United States for further studies or internships in factories. It was originally planned to select more than 300 people to go to the United States; however, due to the tense domestic situation during the Civil War and the severe shortage of foreign exchange, by 1947, only about 90 people made the trip (W. Zhang & Wu, 2008). Although the technology induction was far from achieving the expected results, those who went to the United States had received professional training. After the Civil War, most of them stayed in mainland China to participate in independent research and development of equipment and technology, eventually making significant contributions to PRC's power industry (Z. Wu, 1988, p. 84; Yun, 2000a, p. 361).

The highly developed elements adding to the initial stage of China’s electrical science and engineering development owes to the international connections and the development of domestic talent. However, the radical political periods: Thought Remoulding (1951-1952), Great Leap Forward (1958-1960), and the Cultural Revolution (1966-1976), which were repeated episodes of persecution of scientists and intellectuals, delayed the power system from being transformed into a modern network. The anti-intellectual policies stemmed from Mao’s political distrust of the Chinese scientific and technological elites that the PRC inherited from the Nationalists and even those the new government had beckoned to come back from the West. The Thought Remoulding campaign of 1951-1952 pressed scientists and other intellectuals, using psychological and physical violence, into political loyalists (Zuoyue Wang, 2015). However, the party’s moderate and pragmatic leaders, such as Premier Zhou Enlai, Marshal Chen Yi, and Marshal Nie Rongzhen, were more sympathetic toward and supported Western-trained scientists and engineers (ibid). Under the direct leadership of Premier Zhou Enlai, PRC’s Chinese Academy of Sciences, which inherited the research infrastructure as well as the scientific-technological community from the Nationalist Academia Sinica, attracted a thousand Chinese scientists and engineers from the United States to China (Zuoyue Wang, 2014). These elites kept adding advanced development elements of Western science and technology to the Chinese system in Mao's era that was shadowed by the Cold War, albeit 'in subtle and unheralded ways' (Zuoyue Wang, 2014, p. 351). In the Great Leap Forward movement of 1958-1960, the scientific and technological elites were reassigned to rural areas to solve mundane production problems. The central government lowered professional standards to rapidly expand the scientific and technical personnel. The economic degression and famine following the Great Leap Forward campaign and the sudden withdrawal of Soviet experts in 1960 brought a renewed but short-lived period of domestic technological advancement and international scientific and technological contact with the United Kingdom, France, Sweden, Australia, Denmark, and Switzerland in the early 1960s (Zuoyue Wang, 2014, p. 358). However, the Cultural Revolution ceased all the international scientific and technological connections and educational cooperation, thereby stalling the Chinese power industry from becoming a modern system.

3.3 The years of turbulent growth (1953-1978)

Having suffered from long-term war, the newly established Chinese government faced its vulnerable economic foundation. In 1949, China's GDP per capita ranked among the world's lowest. The total electricity generation capacity was 1.85 GW to support a population of about 540 million; by contrast, the United States generating capacity during the same period was 63 GW for 150 million citizens (Andrews-Speed, 2018; Jowett, 1984). Only 33 small hydropower stations supplied electricity to rural regions; 90 per cent of the total population consumed only 0.58 per cent of the total electricity consumption (Peng & Pan, 2006). The first three decades after the People's Republic of China's founding in 1949 was directed by Maoism under an economic planning system. Under the planned economy system, the power sector was vertically integrated and headed by the industry ministry. Appendix C displays a comprehensive review of the policies, institutional frameworks and critical events after 1949. After a three-year recovery period, starting from the first Five-Year Plan in 1953, the central government regarded the power industry as the leading industry in the national economy. It injected significant capital into the electrical equipment manufacturing and generation systems (CEPYC, 2002, p. 22).

3.3.1 Maoism: technological revolution

Just as Thomas Parke Hughes (1983) argued that power systems are 'cultural artefacts' (p. 465) that 'embody the physical, intellectual, and symbolic resources of the society that construct them' (p. 2), China's power system is deeply embedded with the important values in Maoism. Mao had upheld 'serve the people' as the Chinese Communist Party (CCP)'s fundamental purpose and pledged to 'the liberation of the people and work entirely in the people's interests' (Mao, 8 September 1944, p. 227). Equality and egalitarianism were among the essential values in Maoist China (Lovell, 2019). Thus, facing the mass population in rural China and the severely uneven electricity distribution, Mao followed Lenin's dictum that 'Communism is Soviet power plus the electrification of the whole country' (Lenin, 22 December 1920) and declared his desire to electrify the countryside. Rural electrification was not only one of the priorities on Mao's agenda but also on that of his successors. Thanks to the determination to deliver electricity to China's entire population, China endeavoured to master the technology of constructing and operating high-voltage transmission lines and has achieved control over cutting-edge ultra-high voltage (UHV) technologies (Y. Xu, 2019).

The other priority Mao placed on his agenda was industrialisation. He highlighted that 'The emphasis in our country's construction is on heavy industry. The production of the means of production must be given priority' (Mao, 25 April 1956) and gave the highest priority to generating adequate electricity to support the need for rapid industrialisation. In 1958, Mao reiterated the importance of the electricity industry at the Supreme State Conference. His guiding ideology that 'electricity is the "pioneer" of the economic development and power sector should take the lead to meet the needs of industrial and agricultural production' (Mao, 1965) was repeatedly mentioned by subsequent leaders. The Ministry of Power Industry was established, as the policymaker, regulator, and operational manager, to support the energy-intensive industries' rapid development. Mao's insistence on economic development dominated by heavy (polluting) industries triggered the Great Leap Forward from 1958 to 1960, a period of blind expansion and recklessly wasteful investments. The radical growth of the steel and iron industries caused severe environmental degradation (Bramall, 2008). The emphasis on scale permeates Chinese policymaking and is particularly prominent in the power sector. For example, the overbuilding of thermal power plants from 2013 to 2016 was an exemplar of the ‘Great Leap Forward-style’ investment.

Mao, de facto, treated technology very seriously, despite, as mentioned in the previous subsection, he politically suspected the western-educated scientific and technological elites. In line with the development and widespread notion of ‘science as a force of production’ in the communist world, especially the Soviet Union and the German Democratic Republic, in the mid-1950s (Buchholz & Blakeley, 1979; Schramm, 2018), Mao put forward a technological revolution in 1956. He stressed again in 1958 that ‘the party’s focus of attention can be transferred to a technological revolution’ and ‘we must start a technological revolution’ (Mao, 2 February 1958). He further highlighted the importance of innovation and declared that ‘we must break away from conventions and do our utmost to adopt advanced techniques to make China a powerful modern socialist country in not too long a historical period’ (Mao, 13 December 1964).

Subsequent leaders followed his advocacy. Notably, after Xi's succession, he placed the invigoration of the country through science, technology and education at the core of national development (Xi, 2014). On the other hand, Mao criticised Stalin’s advocacy of ‘technology decides everything’ (Mao, 1958). He underlined that ‘politics and technology must be combined together’ and declared that political work is the ‘guarantee for the accomplishment of technological work’ and ‘a slight relaxation in our ideological and political work will lead our economic and technological work astray’ (Mao, 31 January 1958). He also demanded that politicians must have some knowledge of technology (ibid). Indeed, most of the following generations of China’s top leaders have a science and engineering education background. Notably, the then-premier Li Peng trained in hydroelectric engineering at the Moscow Power Institute from 1948 to 1955 and started his career in power sector administration (P. Li, 2014). He became the Ministry of Electricity minister in 1983 and was quickly promoted to be the premier from 1988 to 1998. He was one of the leading figures in China’s power sector, and his career illustrated how ‘electrical and political power have frequently reinforced each other within the Chinese party-state' (Yeh & Lewis, 2004, p. 454). The political support has promoted China's technology leapfrog in recent years; on the other hand, the intimate relationship between politics and technology has hindered and constrained changes and diluted the effects of changes.

It is also worth noting that Mao acknowledged the desperate need for professional people in his early years. In his essay *On the People's Democratic Dictatorship,* which was published a few months before the founding of PRC and indicated the immediate policy directions of the new China, Mao declared that 'our present policy is to regulate capitalism, not to destroy it…we must unite with the national bourgeoisie' 'learn what we do not know… learn…from all who know how, no matter who they are… must esteem them as teachers, learning from them respectfully and conscientiously' (Mao, 30 June 1949). His formulations allowed the CCP to attract support from business people, professionals, and intellectuals who strived for rebuilding China as an industrial state (Davin, 2013). Thus, after the civil war, the majority of educated Chinese, who once worked for the Nationalist Government, stayed, participating in the reconstruction of the country.

Although many engineers received their professional training in the United States and admired its advanced technological systems and many of them felt negative about the Soviet Union because the Soviet army plundered the northeastern China of its industrial equipment when it liberated the region from Japan (Davin, 2013) at the end of the Sino-Japanese War. However, given the establishment of diplomatic relations with the United States was fruitless, they had to seek an alliance with the Soviet Union. Also, as mentioned above, Mao's distrust of the Western-trained Chinese scientist and engineers led to the party's belief in relying on Soviet technical assistance to accomplish the developmental technological goals. Thus, Mao made it clear that 'the Communist Party of the Soviet Union is our best teacher and we must learn from it' (Mao, 30 June 1949).

3.3.2 The Soviet Union

CCP's relations with the Soviet Union influenced the growth of China's electricity industry. Mao's China is often characterised as isolated (Mitter, 2016); however, China was exposed to a new foreign influence from the Soviet Union. To reconstruct the battered economy of the new China, Mao took cues from Josef Stalin of the Soviet Union. He adopted the custom of five-year plans and constructed China's economic system as one composed of entirely state-owned firms and agricultural communes.

The 1950s marked the high point of Soviet impact on Chinese politics, economy, and culture, with Soviet technical missions, economists, diplomats, and writers together all shaping the new communist China. Starting from the first Five-Year Plan (1953-1957), China invited Soviet experts to assist in building the power system and adhered to Stalin's model of the highly-centralised socialist planned economy. At the end of the Soviet-style first Five-Year Plan, 156 major industrial projects were constructed with the help of the Soviet Union (NPC, 2010) and the total electricity generation capacity tripled (see Figure 3-1).

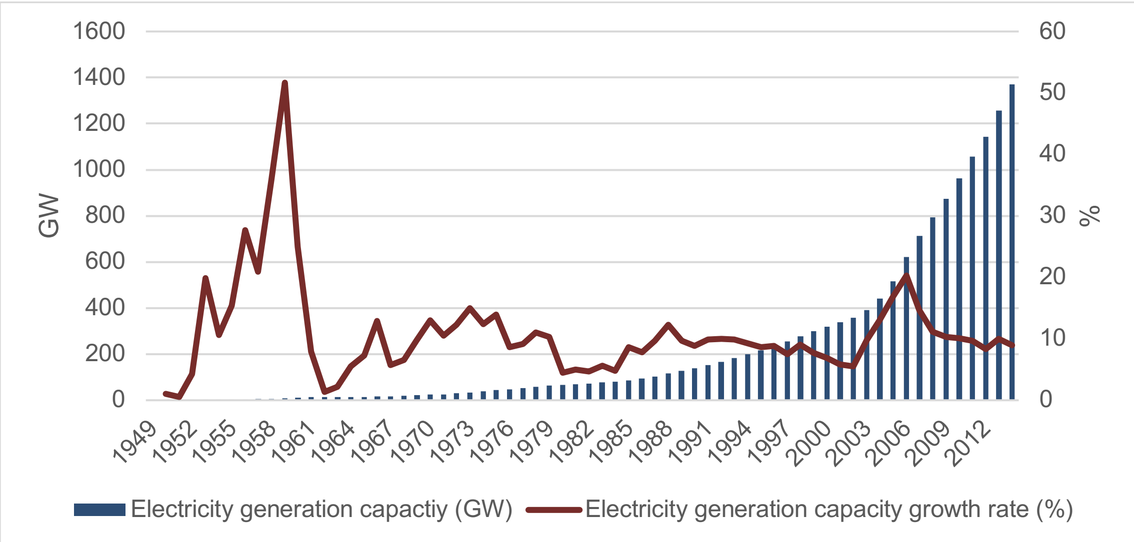

Figure 3-1 Electricity generation capacity and the growth rate (1949-2014)

Source: China Energy Databook (CED) (2016) v.9.0 Lawrence Berkeley National Laboratory. CA.

The Soviet assistance in the 156 projects, including the expansion and construction of electric power stations (see Appendix D for details of electric power projects), lied in three specific mechanisms that were the transfer of complete technological installations, the retention of foreign specialists and consultants, and the travel of students to study abroad and the travel of worker for each of the Soviet-aided plants to receive special training in Soviet factories

(Lardy, 1987; B. Zhang, Zhang, & Yao, 2006). The Soviet Union aided these projects 'from beginning to end' – from sites selection, feasibility studies, blueprints and working drawings preparation to the supply of equipment and technical data, installation of machinery, and the training of Chinese personnel (CIA, 1955; Lardy, 1987). In addition to large-scale export of equipment and raw materials to China through aid projects, the Soviet Union also carried out scientific and technological cooperation with China sharing technical documentation. It assisted China in scientific theory and experimental research. At the same time, the Soviet Union helped China adjust the higher education system, established many technical schools, and admitted numerous Chinese students and interns.

The 156 Soviet-assisted projects also proved artefacts as congealed culture and dominated by Soviet culture in this period. During the years of the 156 projects, various Soviet experts, ranging from technical consultants and engineers to specialised workers, worked on every site to provide technical supports and conduct workshops and training classes, which enabled Soviet technology and culture to take root, grow, and bear fruit in China (B. Zhang et al., 2006, p. 142). The presence of Soviet advisers, the preference for building very large-scale industrial enterprises, widespread adoption of Soviet techniques and methods of economic planning, management and control procedures, and industrial processes created China an economic system which was a close copy of the Soviet system. Thus, the Soviet assistance to the 156 projects exerted significant influence upon the Chinese economy and institutions.

The technology transfer from the Soviet Union to China in the 1950s laid the foundation for China's modernisation and industrialisation, enabling China to build a relatively modern technology system and promote scientific research development (B. Zhang, Zhang, & Yao, 2004). Although the Soviet highly centralised planned economic development model enabled the CCP to pool all resources and coordinate efforts to complete critical national undertakings, it exposed many inherent drawbacks. Under the planned economy model, enterprises and the local government lacked innovation motivations and lost enthusiasm for technological research and innovation. It also led to low economic efficiency and the aforementioned Great Leap Forward style of overinvestment.

When it came to the 1960s, China cut ties with the Soviet Union, and Soviet experts withdrew from China, leaving China isolated with no external technology or capital support. China was in a critical time desiring intellectuals and scholars to push forward its technological innovation and economic development; however, China fell into a maelstrom of internal political struggles leading to the ten-year Cultural Revolution. From 1966 to 1976, many experts in the energy sector were persecuted and expelled, and the power sector's development stalled.

3.4 'Crossing the river by feeling the stones' (1978-2002)

With the death of Mao in 1976 and Deng Xiaoping's accession in 1978, China's political and economic development entered a new era. Deng was a pragmatist, advocating 'it does not matter if a cat is black or white, so long as it catches mice'. He discarded one of Mao's most important values, equality and egalitarianism, encouraged individual economic success, and cultivated the entrepreneurial spirit. He abandoned the central tenet of Soviet-style communism, promoted freeing the economy from constraints of Marxist dogma, and abolished the centrally planned economy to unleash market forces and allow individual participants in the economic activities. The nationwide 'Reform and Opening Up' campaign triggered a new round of industrialisation that needed a sustained increase in electricity supply. However, severe power shortages hampered economic development. The reason for the power shortage was the severe shortage of construction funds, which was in accordance with Thomas Parke Hughes (1983)'s findings that the primary problems became less technological and more financial and managerial when the power system grew from a local to a regional scale. Accordingly, the central government initiated a revolution in financing and institutional frameworks.

3.4.1 Financial innovation

Before the 1980s, the state was the single fund provider. Due to the lack of national finances, the funds available for investment in the power sector were limited and far from meeting large-scale power construction needs. Thus, aiming to incentivise power sector investment, the central government embarked on granting the third parties outside the central government to invest in power plants (StateCouncil, 1985). It started by giving the local government the authority to participate in financing electricity infrastructure projects. Longkou thermal power station was the first successful case of the industry's financial innovation.

At the end of 1980, Li Peng, then deputy minister of the Ministry of Electricity, came to Shandong Province and walked on the road of Jinan, the provincial capital, with Zhou Jingzun, the then director of the Shandong Electricity Bureau.[8] Li asked how Jinan did not even have a neon light. Zhou said we did have lights, but we did not have electricity to light them because you (the Ministry of Electricity) did not appropriate the fund. Then they discussed that they might be able to learn from other countries about bond financing. Zhou suggested building the power plant in Yantai, which was near the seaside and rich in coal. Li agreed with his proposal. After the conversation, Zhou drafted a document for the bureau (N. Xu, 2016).

It was still in the planned economy era; breaking the government funding model and issuing the bond was undoubtedly a bold idea. However, to address power shortages, the local authorities decided to give it a try. In April 1981, the provincial government approved the proposal of issuing the 'bond' to finance the construction of the Longkou thermal power plant. The Chinese character on the certificate (Figure 3-2) is 'Stock'; however, it is entirely different from the stock we refer to today. It would not be issued in the stock market. Instead, it was similar to bonds with a five-year duration. The power plant paid the principal and coupon. In August, the Ministry of Electricity agreed to entrust the Shandong Electricity Bureau and Yantai municipal government to jointly build and operate the power plant. Of the CNY204 million needed for constructing the Longkou power plant, 30 per cent was funded by the state, and the municipal government raised 70 per cent through bond issuance. The subscription was open

[8] The illustration of the establishment of the Longkou power station was based on N. Xu (2016)'s interview with the former general manager of Shandong Electricity Bureau, P. Li (2005)'s diaries, and news published in the local newspaper (Lu, 2018).

to the public, and the power distribution was guaranteed in proportion to the investment. Township and village-run enterprises were the primary buyers of the bond, buying 72 per cent of the bond in total, while the remaining shares were purchased by collective enterprises above the county level (18 per cent) and the state-owned enterprises (10 per cent) (Diao, 2018). The investors received the principal and interest one year earlier. After the power plant was put into operation in 1984, it generated 1.2 billion kilowatt-hours (kWh) of electricity in 1985, which completely solved the region’s power shortage problem and boosted the economic growth of Yantai and made them one of the wealthiest cities in China.

Figure 3-2 Subscription certificate of Longkou electricity infrastructure fund
Image from Lu (2018)

The success of financing the Longkou power station highlighted the local government’s capabilities and strengthened the central government’s confidence in decentralisation. During the sixth Five-Year Plan from 1981 to 1985, the state delegated more power for planning and financing electricity infrastructure to provincial governments. As a result, 19 central-local government joint financing power infrastructure projects were constructed (W. Chen, 2007). In 1985, State Council released an official policy to encourage local governments, state-owned enterprises (SOEs), private sector investors and foreign companies to invest in the power sector. It further clarified that fund-raising power plants could operate independently (StateCouncil, 1985). The investment return rate would be guaranteed by a power purchase agreement

(PPA) that generators have with the grid companies with predetermined utilisation hours and power prices. Power plants also could entrust the electricity bureau to operate and manage the power plants on their behalf. The electricity sales prices were allowed to float for the former ones, which attracted vast private and foreign investments in the power sector through joint ventures.

In September 1987, the then Vice Premier Li Peng proposed a reform plan of 'separating government regulatory and enterprise operations, making provinces as entities, uniting power grids, unifying dispatching, and raising funds for power generation' (P. Li, 2005, p. 972). Later on, a statement on levying two cents per kWh for all enterprises as the electricity construction funds was announced by the StateCouncil (1987). In 1988, the power sector reform plan was officially launched with the approval of the State Council. A 'fair dispatch rule' was introduced to ensure 'transparency, equity and fairness' in dispatch (StateCouncil, 1988). It was reinforced in 2003 to ensure fair competition in the newly established electricity market (SERC, 2003a) and promote optimal inter-provincial dispatch to address the unbalanced distribution of energies (SERC, 2003b). Together with the fair dispatch rule, the PPA contract substantively incentivised power sector investment and boosted the power supply capability.

Ertan hydropower station was an exemplar of diversifying the financing strategies for power development. It was then China's largest hydroelectric project in the 1980s. The project was proposed by the China International Engineering Consulting Corporation at the request of the State Development and Planning Commission (SDPC) (the former National Development and Reform Commission) in 1986 and approved by the State Council in 1987. The World Bank provided a 780 million US dollar loan with a 20-year term, including nine years of grace (WBG, 1991, 2002a). The project was significant in the history of China's hydroelectricity development, not only because of its capacity of 3,300 megawatts (MW) and 17 Terawatt-hour (TWh) a year, but also 'the transfer of modern technology, staff training, least-cost investment planning and modern utility practices' (WBG, 1991, p. 24). The gestation period of large hydroelectric projects in China was shortened from 15 years to nine years. However, the financial outcome was 'moderately unsatisfactory': the internal financial rate of return was between 6 per cent and 9 per cent, below the target of 12 per cent; the rate on revalued assets was 3.9 per cent, much lower than the estimated 15 per cent; the debt-equity ratio was 98/2 rather than the proposed 70/30 (WBG, 2002a). Hu (April 2000) reported the project was burdened with a loss of CNY one billion in 1999 and expected to be higher in 2000. J. Wang (2000) concluded that the unsatisfied performance was a result of Sichuan-State Power Corporation's failure to abide by PPA, which led to distorted dispatch and pricing policies; and a consequence of the Sichuan-State Power Corporation's mishandling of the effects of Asian economic crisis, which led to the excess capacity in this region. Also, the excess capacity could not be transmitted to regions with insufficient electricity supply due to underdeveloped interprovincial transmission lines (WBG, 2005). Checking the Project Implementation Completion Reports (WBG, 1997, 2002b) and the Project Performance Assessment Report (WBG, 2005), it can be seen that the PPA signed between Ertan Hydroelectric Development Corporation and the Sichuan-State Power Corporation had stated pricing principles and dispatch arrangements. However, the reports all indicated that the pricing formula was not state-of-the-art as the price-setting was left to the government, not the market (WBG, 2002a, p. 11), and more importantly, there was a lack of a legal framework to adjudicate the defaulter (WBG, 2005). Thus, when Ertan Hydroelectric Development Corporation had difficulties getting the terms of its PPA observed, the regulatory framework hardly progressed. The weaknesses of legal mechanisms still exist in the current power system.

Besides the financial innovation in domestic local financing tools and attempts to seek loans from multilateral lending institutions, foreign direct investment (FDI) was also a crucial financing mechanism to cover the power sector's financing shortfalls. Deng opened up the coastal regions to attract foreign trade and investment and encourage technology transfer through the low tax rate and simplified bureaucracy in the 1980s (Bramall, 2008). Recognising the lack of required financial resources and the manufacturing wherewithal to supply the needed generating equipment and the need to enhance the energy efficiency, the central government later removed the regulatory barriers and restructured feed-in-tariff schemes to allow and attract FDI (Blackman & Wu, 1999). China became the most significant FDI recipient. By the late 1990s, about 120,000 foreign-invested companies in China (Murray & Cook, 2013) accounted for 40 per cent of the total FDI inflows to all the developing countries (Broadman & Sun, 1997). The inward FDI not only filled the financial gaps in the power sector, but also potentially enhanced energy efficiency through the transfer of advanced generating technologies and management techniques (Blackman & Wu, 1999; Z. Li, Gallagher, & Mauzerall, 2020).

By 1997, the nationwide power shortages were diminished. For the next five years, the demand for electricity were met, mainly due to the growth rate declining during the Asian Financial Crisis. The other point worth noting is that the performance evaluation of a power project proposed in the 1988 reform plan is based on total capacity rather than economic benefits, which the generation segment has endorsed until recent years.

3.4.2 Institutional reform

Despite the 1980s reform that has broken the state monopoly and gradually opened the power generation market, the power sector remained under direct ministerial control. The unification of government and business functions in the power sector remained, and the central government still controlled grid assets. Concerned with the high economic burden on the government and the large scale of financial losses incurred by many SOEs because of the 1997 financial turmoil and learning of new ideas from abroad (Andrews-Speed, 2018), the central government took a significant step to reform the institutional framework of the electricity industry in 1997.

Following the enactment of the Electricity Law in 1996, the central government formed the State Power Corporation (SPC) to take over the enterprise management function from the Ministry of Electricity. Most of the power sector assets were transferred from the Ministry of Electricity, and the local bureaus were renamed as companies within the SPC. In 1998, the Ministry of Electricity was abolished, and the government function was transferred to the State Economic and Trade Commission (SETC). While SETC was responsible for the regulatory oversight of the enterprises, SDPC was charged with the national planning and strategy development for the energy sector and held approval authority over major investments in generation and transmission. The reorganisation of the power sector marked the first step towards the separation of government regulatory and market operation.

SPC only existed for five years and dissolved in 2002. An investigation report released by Hu (April 2000) on the hydro curtailment incident in Sichuan Ertan hydroelectric station triggered the reform of dismantling SPC. In his report, Hu criticised the monopoly of SPC and local protectionism. Subsequently, in May, the then director of the electricity department of SDPC, Wang Jun, published an article claiming the power sector reform led by SPC was frustrating. J. Wang (2000) attributed the high curtailment of hydropower in the western region to SPC and blamed SPC's monopoly behaviour for causing low efficiency and high pollution in the power sector. He advocated anti-monopoly within the power sector and suggested the reform should be 'top-down' being led by the central government. As soon as Wang's article was published, it attracted significant attention from the industry and the central government. Accordingly, in October, State Council appointed SDPC to lead the reform, requiring SPC and SETC to cooperate with SDPC to carry out reforms (StateCouncil, 2000).

In 2000 and 2001, intensive debates took place involving the highest government levels, and senior officials published their arguments for further reform in the press (Liu, 2015). From 2000, SDPC took responsibility for drafting a new reform plan. Wang Jun, who publicly criticised SPC for making no effort to reform the industry, led the power sector reform team. At the end of 2002, a final decision was made by StateCouncil (2002) to dismantle SPC and separate generation from transmission and distribution.

3.5 Forming the Chinese style (2002-2015)

In December 2002, the State Council released the power sector reform plan, referred to as Document No.5, which embarked on a new round of power sector reform. The core objectives defined in the document are promoting the role of the market in the development and operation of the power sector and applying effective economic regulation to the electricity sector to ensure efficient and reliable power supplies and protect the environment (IEA, 2006). A new series of electricity sector reforms have been carried out under Document No.5. Primary reform measures have been executed to separate electricity plants from electricity grids, restructure the central generation assets and electric network assets, construct regional electricity markets, and set up professional electricity regulatory institutions (StateCouncil, 2002).

3.5.1 Restructuring the electricity market

This round of reform's structural focal point was to eliminate the SPC monopoly by disaggregating the SPC generation assets and grid assets into five generation companies (the Big Five), two grid companies, and four power service companies (see Figure 3-3). The new Big Five were all SOEs. Each of them was given about one-fifth of the SPC generation capacity as a means to introduce competition, ensuring no single company held more than 20 per cent of the market share in a certain geographic region. The transmission and distribution assets of the SPC were divided between two new companies. The State Grid Corporation owned and controlled the majority of the regional grids in the country. It was authorised to construct and operate the interregional transmission lines. It consisted of five subsidiary regional grid companies, each responsible for interprovincial transmission in its geographic region. Each of the five regional companies also had subsidiary local grid companies. Meanwhile, the Southern China Power Grid Company took over the assets in the far south of the country. The four power service companies were distributed with key ancillary services that had been previously integrated into the SPC.

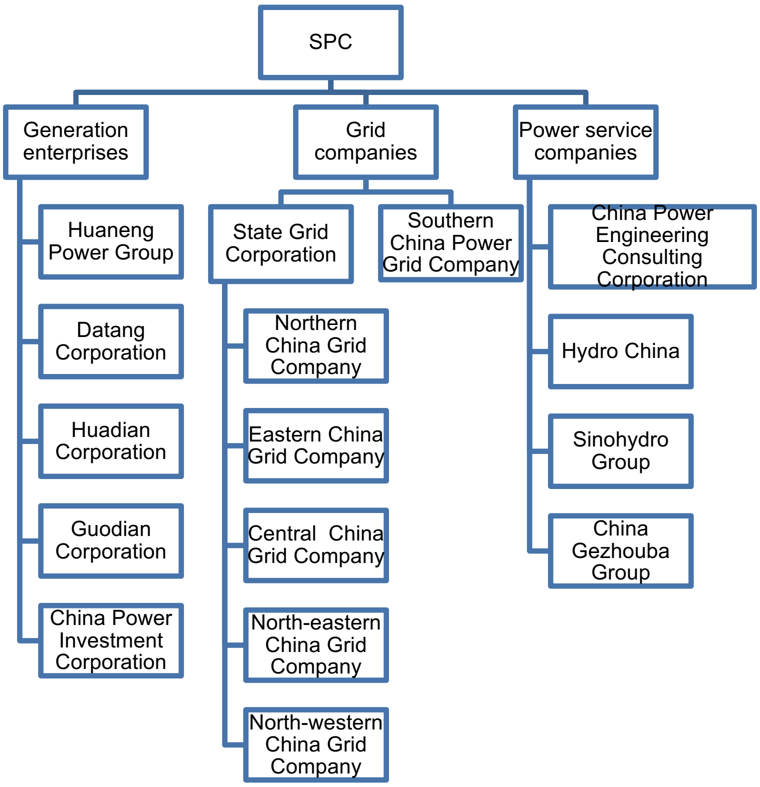

Figure 3-3 Unbundling SPC in 2002

Source: Liu (2015, p. 203)

After the unbundling, each of the big five companies controlled around 32 GW of capacity (WBG, 2007) and started to expand its generation capacity in different geographic regions. By 2017, the Big Five, each with more than 100 GW of capacity, had a total installed capacity larger than countries like the United Kingdom (IEA, 2018). The Big Five also underwent rapid changes in subsequent years. The China Power Investment Corporation merged with the State Nuclear Power Technology Company in 2015 to form the new State Power Investment Corporation. Guodian merged with Shenhua Group, a coal giant, in 2017 to form the new China Energy Corporation. Figure 3-4 presents the current major players in the electricity market. In total, the Big Five control around half of the generation capacity across the country. The remaining half is owned by a wide range of industrial enterprises at the local level.

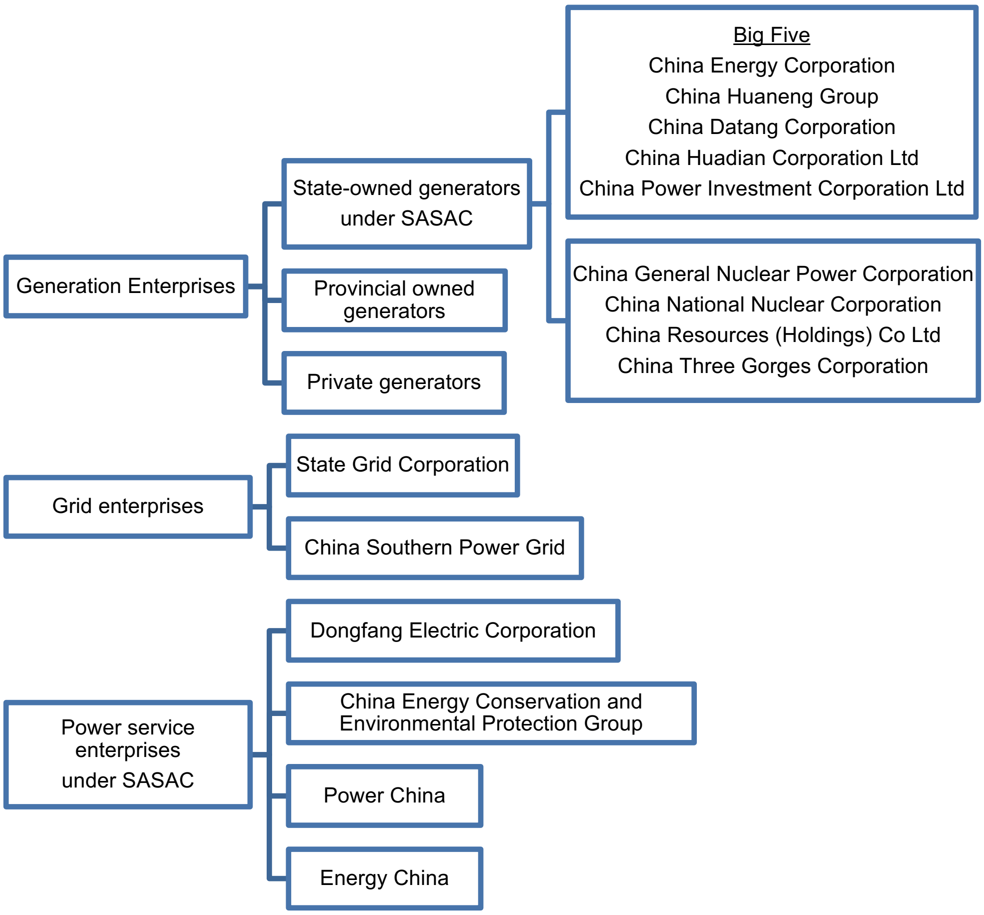

Figure 3-4 Key players of China's electricity industry, 2018
Source: http://sasac.gov.cn/

Despite the radical restructuring of the electricity system, distribution was not separated from transmission, and the function of dispatch was not separated from grid ownership. The state dispatching centre within the State Grid Company remained responsible for dispatching the interregional transmission lines and facilities. Regional dispatching centres within each regional grid subsidiary continued to be responsible for dispatch within the region. Grid companies acted as a single transmission and distribution system operator, plus a single buyer on the wholesale side and a single seller on the retail side. As regulation was insufficient, sometimes, each regional grid firm tended to favour its own portfolios, which discouraged interprovincial and interregional trading. Also, there was no separate transmission and distribution tariff, making it challenging to know accurate investment and operation costs. These issues were stressed in the next round of power sector reform.

3.5.2 Restructuring the regulatory agencies

Followed by the break-up of the SPC, the State Electricity Regulation Commission (SERC) was established to serve as an independent regulatory body for the newly restructured power sector. Priority duties of the SERC were to establish rules to form competitive power markets, with authorisation for supervising interprovincial power transmission, policymaking and implementation (StateCouncil, 2002). The founding of SERC was a breakthrough for the sector (Yeh & Lewis, 2004), showing a clear sign of China's commitment to professional regulation in the power sector in order to control the behaviour of natural monopolies, promote fair competition and promote the public interests (WBG, 2007).

However, its professionalism and independence were questionable for three major reasons. First, from the SERC's establishment in 2003 to its revocation in 2013, the Electricity Law, enacted in 1995, was not revised accordingly. The absence of a new Electricity Law means that SERC has still not been given the necessary legal duties and therefore does not command the required authority with the regulated enterprises (Liu, 2015; WBG, 2007). Second, SERC was set up as a professional regulator. However, the core functions of electricity regulation – electricity pricing and generation capacity planning and approval – have not been allocated to SERC but are maintained by the National Development and Reform Commission (NDRC). This severely limited the capacity of SERC to regulate the electricity sector effectively and intensified the functional overlaps and conflicts between government institutions. Third, the vertical division of functions and numbers of personnel within SERC was far from adequate (WBG, 2007). Also, the personnel quality within SERC was a big challenge for executing the critical regulatory tasks. This problem existed because the wage gap between SERC and the state-owned electricity enterprises placed SERC in a relatively inferior position in attracting high quality and talented staff within the electricity sector compared to SOEs.

A research report (WBG, 2007) on the capacity building of the SERC co-published by the SERC, the Ministry of Finance, and the World Bank in 2007 had developed recommendations for improvement, the most important of which was the reallocation of responsibilities. Notably, it emphasised that 'there should be a gradual adjustment of the responsibilities for tariff setting, so that they are progressively transferred to SERC from NDRC' (WBG, 2007, p. 121). However, so far, NDRC still controls the pricing. Electricity price adjustments still rely on administrative instructions rather than market-based bidding. Despite SERC positively influencing China's power market transition progress in general, it eventually dissolved ten years after its establishment mainly because the NDRC resisted to change (Liu, 2015). In 2013, the SERC merged with the National Energy Administration (NEA), a department established under the NDRC.

The current power sector governance structure, as shown in Figure 3-5, is mostly formed in this round of reforms. NDRC held approval authority over major investments in generation and transmission, retained the authority to set electricity prices and maintained charge of integrating the power industry plan within the macroeconomic development plan. NDRC ensures the targets of power sector reform do not collide with the broader national economic targets. Other than NDRC, several other ministries are involved in power policies. While NDRC takes responsibility for electricity tariff regulation, the Ministry of Finance (MOF) takes responsibility for electricity cost regulation. Given its authority on specific financial rules and cost standards for electric enterprises, MOF has decision-making powers relating to the electricity sector. Although WBG (2007) emphasised that 'bringing tariff regulation and cost regulation together is critical for the development of effective regulation' (p.152) and suggested that 'the responsibility for these functions should be unified and assigned to SERC' (p.152), this issue was dropped with the dissolution of SERC. Until today, responsibilities are still split between NDRC and MOF, which caused obstacles to developing renewable energy projects. The case studies in Chapter 3 and Chapter 4 reflected this problem.

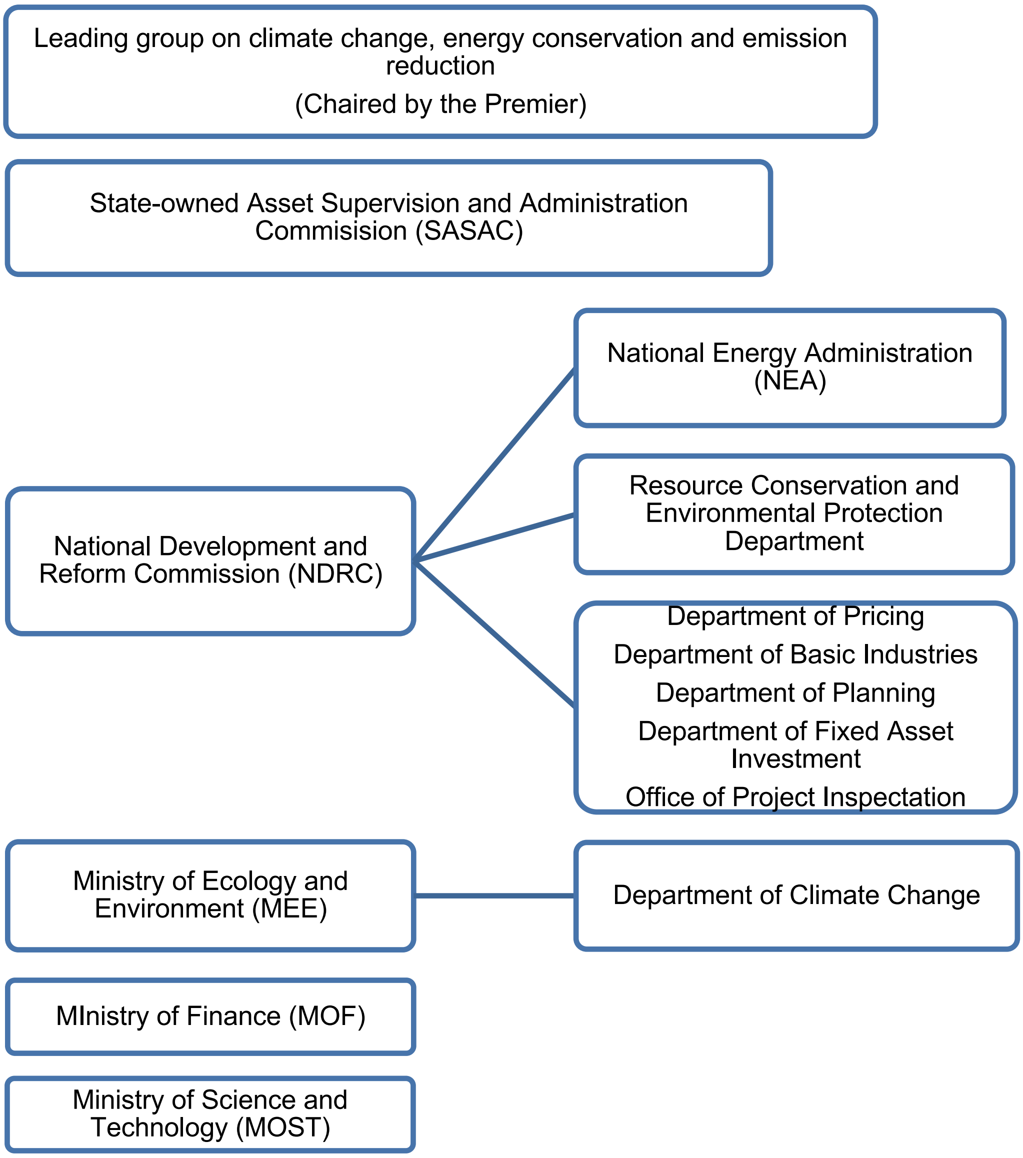

Figure 3-5 Major authorities regulating China's power sectors, 2018
Source: http://www.gov.cn/guowuyuan/zuzhi.htm, http://ndrc.gov.cn/, http://sasac.gov.cn/, http://www.mee.gov.cn/

In 2003, the State-owned Asset Supervision and Administration Commission (SASAC), in its role as owner of state enterprises, was established to execute the functions of government as a shareholder in central-SEOs. It held responsibilities for appointing and removing directors and senior managers, public listing of enterprises, mergers and acquisitions, and asset disposals.

Furthermore, the Leading Group on Climate Change, Energy Conservation and Emission Reduction was set up in 2007. The Leading Group is chaired directly by the premier and is composed of a widely based group of stakeholders from different government areas. The Leading Group takes the responsibilities of international cooperation and negotiation on climate change, reviewing major climate policy recommendations from various government departments and industries, coordinating various stakeholders in tackling climate change, and making unified arrangements for energy conservation and emission reduction (StateCouncil, 2007). The *Climate Change White Book*, released annually since 2008, provides industries with major strategies, guidelines and countermeasures to address climate change. Besides, the State Environmental Protection Agency, which was renamed the Ministry of Ecology and Environment (MEE) in 2018, was enhanced in 2008. It was granted the capacity to monitor and investigate the environmental consequences of large construction projects. Therefore, it became more capable of evaluating proposed power construction projects and power plants' environmental performance (Andrews-Speed, 2013).

3.5.3 Integrating energy efficiency and environmental goals

Another focal point of the reform was integrating energy efficiency and environmental goals into the industry's regulatory framework, ensuring electricity supply could reach an efficient and harmonious co-development with the economy and society (IEA, 2006; WBG, 2007). When Document No.5 was released in 2002, there was a surplus of electricity. However, it quickly turned into a power shortage in 2003 and was exacerbated in 2004 and 2005. The gap between the power supply and demand in 2004 was more than 30 GW, and 26 of China's 31 provinces and major municipalities sustained significant electricity shortages (Liu, 2015; WBG, 2007). Industry experienced enforced closures and consequent losses.

Interestingly, the official opinions of the origins of the widespread blackout starting from 2003 were distinct from those in the industry. At the end of 2003, in response to reporters from Xinhua News, Zhang Guobao, the deputy director of NDRC at the time, explained that the electricity shortage was due to the 'special climate and hydrological conditions' and because of 'the excessive development of certain industries, such as steel and electrolytic aluminium', rather than the slow and insufficient development of power sector (C. Zhao & Liu, 2003). People from various sectors questioned Zhang's explanation, and an article published by Bao (2004) resonated strongly in the industry. Bao (2004) criticised Zhang for neglecting the basic rules of power planning – electric power development should precede the national economy's development – and shirking responsibilities. He concluded that 'rigidly planned economy thinking, arbitrary industry planning and insufficient industry management' (p.33) were the real reasons for the widespread blackouts. Similarly, Liu (2015) pointed out the wrong decisions in the NDRC during 1998-2001. In his book, he cited several articles and speeches published by several electricity planning experts in 1998. The specialists emphasised that the current balance of power supply and demand was only temporary, and the sustainable expansion of the power sector should be continued. They further opposed the implicit rule posed by the NDRC that no new large-scale power generation projects would be permitted for three years (Liu, 2015, p. 221). Several mainstream economic and business newspapers in China also reported similar opinions of a wide range of scholars in business and economics, such as J. Shan (2003) and F. Li (2004). They all pointed out the periodicity of the electricity industry - the construction of a thermal power plant requires three to four years. If new power plants were not built when the economy recovers but built when a power shortage happens, power shortages would occur during the power plant construction period. Unfortunately, their correct assessment did not arouse the attention of relevant leaders and departments. When the economy began to recover after China acceded to the World Trade Organisation (WTO) in 2001, a widespread power shortage inevitably occurred in the following three to four years.

Obviously, from 1998 to 2002, the leading authorities prioritised their work on breaking the monopoly operator SPC rather than maintaining a reliable and sufficient power supply. As shown in Figure 3-6, the growth rate of installed electricity capacity declined from 1998 to 2002, far from reaching the GDP growth rate. In this context, after the SPC finally split up at the end of 2002, the newly established 'Big Five' rushed to build new power projects to expand their market share.

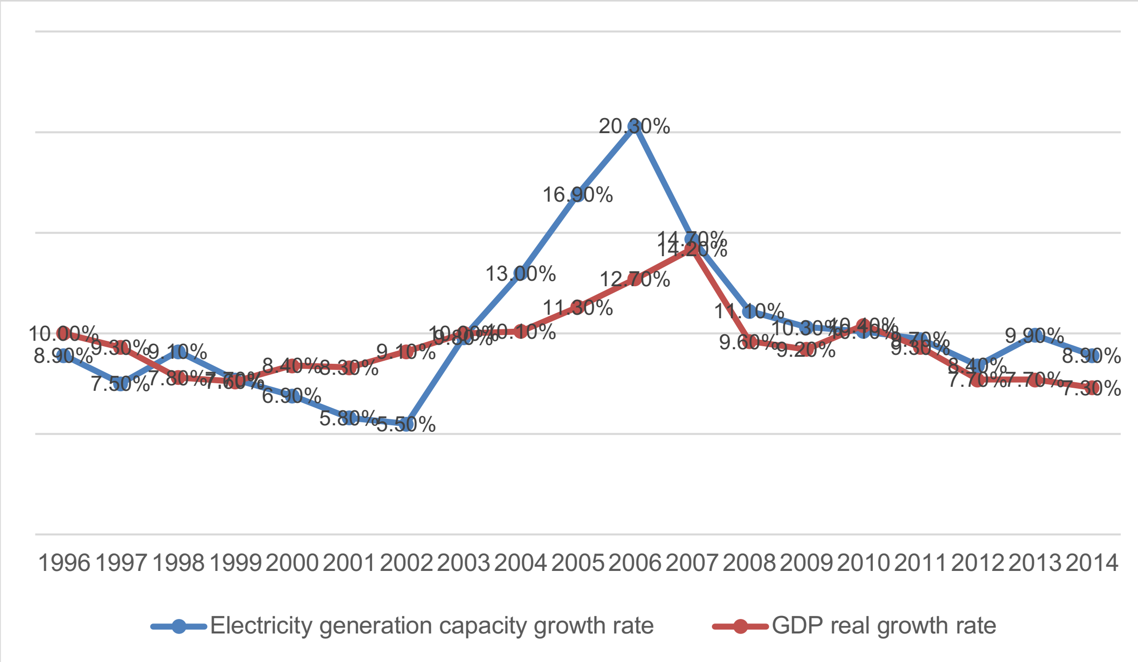

Figure 3-6 China GDP Real Growth Rate and Electricity Generation Capacity Growth Rate (1996-2014)
Source: China Energy Databook (CED) (2016) v.9.0 Lawrence Berkeley National Laboratory. CA.

From 2002 to 2006, the electricity generation capacity grew at a double-digit rate. The rapid growth during this period was bittersweet. On the one hand, the power supply was rebalanced in 2006. China became the world's second-largest electricity producer and consumer next to the United States. On the other hand, as around 80 per cent of the electricity was from burning coal, it became the world's single biggest emitter of greenhouse gases (GHGs) in 2007 (N. Jones, 2007). The electricity generation sector accounted for half of the country's total carbon dioxide emissions and more than half of its total sulphur dioxide emissions (CED, 2016), making it a major source of pollution. Therefore, concerns around energy efficiency and self-sufficiency, economic efficiency and environmental issues prompted the central government to focus on increasing generation efficiency and diversifying the power supply structure. Accordingly, China enacted Renewable Energy Law in 2005 to support the development of renewables. It further enforced an initiative of 'shutting down small power units' (NDRC & NEA, 2007) in 2007 to promote large-scale thermal generation plants and upgraded the emissions standard of air pollutants for thermal power plants to meet international standards. It can be seen from Table 3-1 that China has frequently lifted its emission standards for air pollutants from coal-fired power plants in a decade. Currently, China has more strict standards than those of the European Union, the United States and Japan, which used to rank the world's top three regions with the most rigid rules for coal-fired power plants (X Zhang, 2016).

		Emission limits (mg/m^3)		
China		SO_2	NO_x	PM
Emission standards for air pollutants from thermal power plants (GB 13223-2003)		400	450	50
Emission standards for air pollutants from thermal power plants (GB 13223-2011)	Normal Area	100	100	30
	Key emission limit area[9]	50	100	20
Upgrade and transformation plan for energy saving and emission reduction in coal-fired power plants (2014-2020)		35	50	10
	Beijing (2015)	10	30/80	5
EU		150	150	10
USA		136	95	12
Japan		200	200	50

Table 3-1 Emission standards for air pollutants from coal-fired power plants
Source: Emission Standards for Air Pollutants from Thermal Power Plants (MEP & GAQSIQ, 2003, 2011); Action Plan for Transforming the Coal-fired Power Industry and Upgrading Energy Conservation and Emission (2014-2020) (NDRC, NEA, & MEP, 2014a); IEA Clean Coal Centre (X Zhang, 2016)

Several new initiatives were practised. China extensively retired its older thermal power plants and replaced them with large-scale facilities backed up with advanced coal-fired power technology. It spearheaded the development and deployment of ultra-supercritical boilers – the world's most efficient coal-fired power plant technology, which is consistently highlighted in the Five-year Plans. As shown in Figure 3-7, China has gradually phased out the subcritical plants, and the new builds after 2006 are increasingly ultra-supercritical plants. As a result, average coal plant efficiency improved from 30 per cent in 2000 to 39 per cent in 2018, making China's coal fleet one of the world's most efficient (IEA, 2020a). China's coal-fired power fleet is now roughly 15 per cent more efficient than that of the United States (Davidson, 2019). Meanwhile, the state is

[9] Key regions for pollution control include Beijing, Tianjin, Hebei province, the Yangtze River Delta region, the Pearl River Delta region, central Liaoning province, Shandong province, Wuhan city and surrounding areas, Changsha city, Zhuzhou city, Xiangtan city, Guanzhong region of Shannxi province, Chengdong and Chongqing city, Coastal areas of Fujian province, central and northern Shanxi province, Gansu province, Ningxia province, and Urumqi, Xingjiang Uyghur Auonomous Region

steadily ratcheting up the emission requirements (see Table 3-1) and efficiency standards for those older plants. To meet the world's most restrictive emission standard, the existing coal-fired power plants have to install electrostatic precipitators, flue-gas desulphurisation and selective catalytic reduction systems and upgrade their facilities to combined heat and power (CHP) plants. By the end of the 12th FYP (2011-2015), the installation rate of desulphurisation and denitrification techniques reached around 90 per cent (CEC, 2017). Furthermore, wind and solar power experienced spectacular growth. The central government released a target in 2007 to build 5 GW of wind by 2010 and 30 GW by 2020; however, by 2010, wind capacity had achieved 30 GW (IEA, 2018). China has surged past other markets as the single largest developer of renewable power since 2009 (IRENA, IEA, & REN21, 2018). Between 2010 and 2015, China accounted for more than 40 per cent of the world's newly installed renewable energy capacity and has become the largest renewable energy investor exceeding the United States and the European Union combined (Bloomberg, 2015; Shen & Xie, 2018).

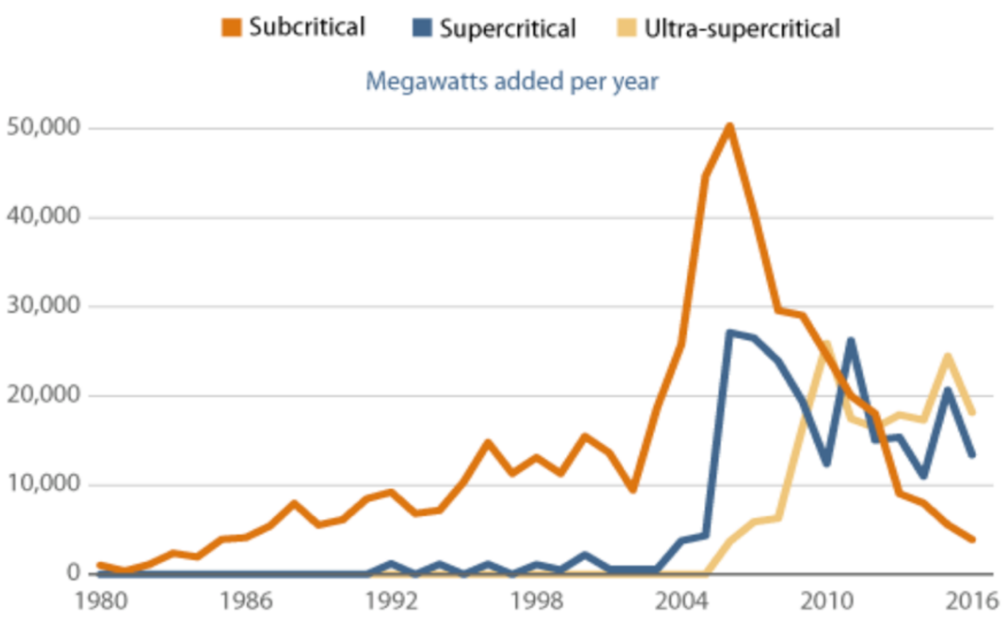

Figure 3-7 Technical makeup of China's coal-fired power capacity additions, 1980-2016

Source: M. Hart, Bassett, and Johnson (2017)

However, not all achievements matched expectations. Particularly pronounced was the low share of renewables in the electricity supply structure and the enormous carbon footprint of coal-fired power plants. Although China has been the leading developer of renewables worldwide, the share of thermal facilities in overall generating capacity still accounted for more than 75 per cent by 2013 (IEA, 2020d). The decade of massive wind and solar energy development only increased the share of renewable energy to less than 2 per cent of the national mix by 2014 (Shen & Xie, 2018). The promulgation of the Renewable Energy Law in 2005 has rectified renewable energy as an integral part of energy policy, which led to a rapid expansion of renewables, particularly wind power, in electricity supply. However, the economic stimulus that followed the financial crisis in 2008 brought a halt to these improvements. To address the global financial crisis's impacts, the central government launched a four trillion yuan economic stimulus in 2009, leading to massive overinvestment in industrial capacity (Andrews-Speed, 2020). The surging electricity demand led the utilities and the government to prioritise the construction of coal-fired power plants. Thus, absolute generation from coal-fired power plants continued to grow in the following years, whereas renewables only accounted for a much smaller fraction of the total capacity than coal. Just as significant, the surge in heavy industry output and coal consumption in power plants exacerbated the already alarming air pollution and enhanced carbon emission. China's carbon dioxide emissions from coal-fired power plants have tripled since 2000, accounting for around one-seventh of global emissions (IEA, 2020a). Internationally, China was severely criticised for 'holding the world to ransom' (McCarthy, 2009) after the United Nations Climate Change Conference of Parties (COP) in 2009. Domestically, protracted episodes of haze and smog outbroke in the winter of 2012 aroused public indignation, which threatened the legitimacy of the CCP and turned urban air quality into a major political issue.

Therefore, when the new administration governed by Xi Jinping took over in 2013, they faced the twin challenges of economic adjustment and environmental protection. At the 18th National Congress, Xi stressed 'never again seek economic growth at the cost of the environment' (Xi, 2014, p. 231) and pledged to build a 'Beautiful China'. It was for the first time the central government put curbing pollution as their top priority. Accordingly, the state declared 'a war on air pollution' in 2013 and called for an 'energy revolution' in 2014 (StateCouncil, 2014a; Xi, 2014). Thanks to the new government's determination to reduce reliance on coal and shift towards a less energy-intensive economy, as shown in

Figure 3-8, the electricity powered by burning coal stopped increasing from 2013 to 2015.

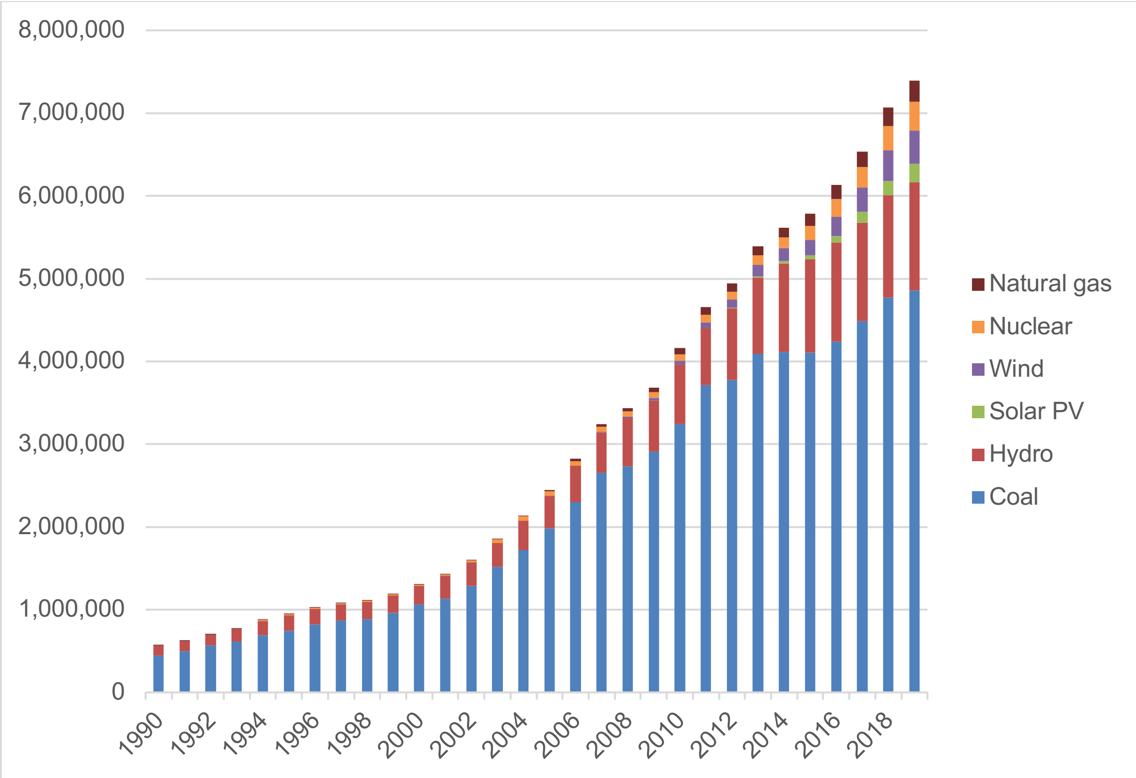

Figure 3-8 Electricity generation by sources, 1990-2019 (GWh)

Source: World Energy Balances (database) (IEA, 2020d)

Another point worth noting is that Xi – son of one of Mao's revolutionary comrades – has reintroduced the Mao-style 'criticism and self-criticism' throughout the state bureaucracy and renormalised Mao's proposition 'mass line' that grass-roots ideas should shape party policy (Xi, 2014). He stresses that 'we must extensively solicit public opinions and suggestions…accept public assessment and supervision…, and make improvements…' (Xi, 2014, p. 425). He also opposes 'blind focus on growth' (Xi, 2014, p. 477) and upholds a sustainable development pattern. The rehabilitation of Maoist strategies has strengthened the power sector's environmental governance and pushed the low-carbon transition. He not only commanded all coal-fired power stations to meet the energy conservation and emission reduction standards within a specific time but also organised the Central Environmental Protection Supervision Team to conduct regular on-site inspections. Weakening the vested interest groups in the power sector creates a favourable market environment for the new entrants, ensuring the feasibility of the subsequent power sector reform (Isoaho et al., 2017; Shen & Xie, 2018).

Meanwhile, in a clear break with post-Mao China's reserved approach to foreign affairs, Xi has reasserted the Communist Party's ambitions to lead the 'world revolution'.[10] China's stance in international negotiation on climate change shifted from reluctant (Lewis, 2013a) to proactive (Hori & He, 2020). In 2014, in the Joint US-China Climate Statement, Xi announced that China would reach its carbon peak no later than 2030 and offered an absolute emissions-reduction target; in 2015, China ratified the Paris Agreement. In this context, China set out a new round of electricity reform.

Decades of market-oriented reform built a supportive environment for innovation and upgrading. Chinese firms have successfully absorbed overseas technology and further contributed to technical advances, and in many cases supplying the resulting products to both the domestic and overseas markets. Examples include supercritical and ultra-supercritical thermal power generation technology and UHV technologies. The central government's desire to maintain high economic growth rates and address environmental issues contribute to the rapid growth of China's solar and wind turbine sectors. A series of aggressive strategies have evolved, including open to competition and foreign participation, to foster Chinese firms' upgrading and innovation. Numerous private solar firms were established by returning Chinese with advanced degrees and rich experience and connections in the industry (Gallagher, 2014). Chinese firms initially concentrated in the downstream stages of the value train for solar, which are panels and modules, sourcing key intermediate components and materials globally (L. Brandt & Wang, 2019). Gradually, they entered all segments of the value chain. The Chinese wind turbine manufacturers initially licensed design from leading international wind turbine companies such as the German Vensys, Aerodyne and Repower, the British Gerrad Hassan, the Dutch Darwind, and the American AMSC (ibid). Subsequently, some Chinese firms acquired the western ones; for example, Goldwind acquired Vensys in 2008.

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[10] In Lovell (2019)'s book, she documented that 'internal documents reported Mao proclaiming that China is not only the political centre of the world revolution, it must also be the centre of world revolution militarily and technically' (p14).

Nevertheless, licensing continues and remains essential. Several leading power generators have acquired wind turbine companies, while some leading wind turbine companies have expanded their business into wind farm development. After the prolonged growth and consolidation, China's power system has an internal drive, acquired momentum, and possesses force and direction.

3.6 Ongoing reform since 2015: the green transition

In March 2015, the State Council released a document, referred to as Document No. 9, symbolising the beginning of China's new round of power sector reform. Prioritising the rapid transition towards a low-carbon electricity industry (NDRC & NEA, 2015a), this round of reform is characterised as 'controlling the middle and deregulation the two ends', which aims to introduce competition into the upstream (generation) and downstream (retail) segments while maintaining the midstream (transmission and distribution) regulated (StateCouncil, 2015a). Redefining the role of grid companies is a breakthrough. Through the wholesale and retail market's opening, grid companies are no longer be the single buyer or the single seller.

Document No.9 is further backed up by the 13th Five-Year Plan (2016-2020) for Energy Development (NDRC & NEA, 2016d) the Electricity Power Industry (NDRC & NEA, 2016b). Notably, it had been 15 years since the last release of the Five-Year Plan for the power sector. Minimum capacity factor requirements for wind and solar were put in place at the provincial level in 2016 (NDRC, 2016). The renewable power generation included in the minimum factor has been mandated to have a priority in making the provincial annual power generation plan. Moreover, together with a policy of ensuring financial support for poverty alleviation (PBOC, 2016b) jointly released by financial systems and NDRC and the Office of Poverty Alleviation and Development, a programme of Solar PV Poverty Alleviation (NDRC & NEA, 2016c) was initiated. Under the programme, villagers could consume the electricity generated from the solar panel and sell excess electricity to the grid firm. The local grid is obliged to purchase such electricity. As a result, the total installed capacity of solar PV surged after 2016 (see Figure 3-8).

Meanwhile, a new round of financial innovation commenced. Building green financial system guidelines were issued that further suppressed polluting investment and encouraged investment in green projects (PBOC, 2016a). A severe overcapacity of coal-powered electricity started in 2015 due to the boost in coal power construction after the administrative approval authority shifted from the central government to the provincial government. Given the underutilised coal-fired power facilities and extensive policies prioritising renewable electricity, most commercial banks have halted issuing loans to coal-fired power projects except CHPs since 2016.[11] Remarkably, in 2017, investments in new renewable power capacity outstripped the amount invested in coal-based generating capacity (IRENA et al., 2018).

3.7 Why history matters?

In this section, I address two questions: Why does history matter to understanding the Chinese energy systems? Why do the historical events matter for the later periods? China's power system has undergone significant changes over the past century, and historical events, policies, and technological advancements have shaped these changes.

History can provide a contextual framework for understanding the Chinese energy system, which helps us understand the drivers of China's energy policy and the factors that have shaped its energy landscape. The country's energy policy has been heavily influenced by the need for self-sufficiency, national security concerns, and the pursuit of economic growth and industrialisation, originating from the wars and economic and social crises. These contingencies push the electricity industry to move in the direction of energy sovereignty, seeking to increase its control over its energy supply and provide reliable energy at affordable prices. Such a goal implies a focus on domestic control over its own energy sources, policies, and infrastructure, reducing dependence on foreign sources and technologies. To increase its control over its energy supply and become more self-sufficient, China recognises the key to investing in energy-efficient technologies and diversifying its energy sources by investing in

[11] The information was revealed in conversations with informants from local commercial banks in the fieldwork conducted between 2018 and 2019, and in the internal documents on the yearly-released guidelines on credit granting criteria for the power plants shared by the interviewees.

renewable energy. Accordingly, the green transition is seen as a strategy that could simultaneously improve energy security and reduce the country's carbon footprint. In short, understanding the historical context of energy systems and transitions can help us better understand the current green transition, including the technological, political, and economic factors shaping the transition.

Additionally, history provides a wealth of information on the mechanisms of change. Dynamic learning is the most important feature for the rapid development of the Chinese power system, wherein essential components such as technological capability-building, institutional restructuring, and capital investment play a crucial part. From the early days of the power system, China opts for the strategy of learning by doing, advocating the advancement of the technological capability relying on the massive accumulation of production capital. This came from the recognition that is increasing the 'absorptive capacity' particularly crucial for the developing country (Gu, Lundvall, Liu, Malerba, & Schwaag Serger, 2009). Herein, knowledge and information from experimentation are indispensable inputs to enhance the absorptive capacity. Jensen, Johnson, Lorenz, and Lundvall (2007) argue that learning can take place through science-based innovation (the Science, Technology and Innovation mode) and by doing (the Doing, Using and Interacting mode); that is, learning is not limited to research facilities that convert local encounters and lab experiments into more widespread knowledge disseminated through training and publication, it also happens through production and consumption. Learning by doing enables users of complex systems and advanced equipment to improve their skills as they encounter and solve issues, building technological capability and enhancing competence.

Another important insight we could draw from the history of the Chinese electricity industry is the crucial role of adaptive policy. Its policy-making process and institutional settings are evolving through trial and error, which characterises 'gradual reforms' in the whole process of China's economic transition (Gu & Lundvall, 2016). Since the 1950s, China has been on the track of catching up, from the centrally planned period (1950s to 1970s) to the market reform era (1980s and 1990s). In this process, there are numerous future scenarios, making it impossible to create a single static policy that will be effective in all of them. Even the best model cannot accurately anticipate all the intricacies of how the system will behave. Thus, policies should be flexible and designed to be resilient in various possible futures rather than optimised for the best-estimated future.

In conclusion, for an industrial latecomer, learning from the advanced economy is always the starting point, while the more important, for the developing countries, is learning from the ‘ongoing experimentation within the system’ (Gu & Lundvall, 2006). The complexity of a system necessitates the need for a learning process as it involves interrelationships among its various parts and components. It is not feasible to develop a reform program that is flawless from the outset, as unforeseen and unknown factors are bound to arise, and climate change further complicates matters. The only way to handle this kind of uncertainty is to build ‘learning’ into the process.

3.8 Conclusion

This chapter reviews China's electricity industry's evolution chronologically from the 1880s, separating it into five main epochs: 1880s-1953, when the system emerged; 1953-1978, when transfer and contestation happened, and the cultural components were added to the system; 1978-2002, when the system grew, more diverse non-technical components evolved to facilitate growth and shape the system; 2002-2012, when the system acquired momentum and style; 2012 to present when the system is being driven towards green transition. It deals with the history of China’s power system in some detail and integrates the broader history and political economy of development over time. Aiming to get the root of changes, it focuses on policy paradigms and priorities, government and industry structures, competing for political and economic interests, the balance between administrative and financial instruments, and the links with trends in the broader economy. It reviews the trajectory of China's power sector, which has delivered a combination of impressive expansion and technological upgrading and environmental footprint. Adopting the system approach put forth by Thomas Parke Hughes (1983), this chapter shows how key elements of the governance of the power sector have co-evolved with broader economic, political and societal context and illustrates the motivations, controversies and compromises in each stage.

The results agree with the findings of Hughes (1983) that power systems are cultural artefacts embodying the physical, intellectual, and symbolic resources of the society that constructs them. As a late developer in a socialist country, the evolution of the Chinese power system is heavily influenced and shaped by international interactions: the American and European imprints that were brought by Western-trained elite scientific and technological workforce; and the Soviet political and technological culture in the form of Soviet-assisted industrial infrastructure. The artefacts congealed various cultures, and these cultures had different dominance at different times that were mainly influenced by political and economic factors. Cultural and external factors gave the power system control and direction. Lenin's electrification campaign with the dictum of communism equals Soviet power plus the electrification of the entire country imprinted the values of equality and egalitarianism in Maoism, which prioritised the rapid construction of the power system as the national development strategy and directed the development of the power system to achieve rural electrification. China stayed in step with other communist regions that developed a communist ideology as science and technology were recognised as a factor of production, initiating the scientific and technological revolution in the mid-1950s. In Deng's era, the value of entrepreneurial spirit led the system to approach liberalisation. The climate crisis pushed the power system to a sustainable transition path, shifting from reliance on coal to renewables. Economic principles, as well as legislative constraints and support, shaped the style. As China changed from a centrally planned economy to a market economy, the power system changed from a centrally planned system with state monopolies towards a more market-oriented structure.

In addition, the evolution of the Chinese power system shares a similar pattern concluded by Thomas Parke Hughes (1983, 1987) that invention and development, transfer and growth, competition and consolidation, and at last, systems acquire style and momentum. The findings also shared Hughes's insights on the most active decision-makers in different stages. Engineers built the system and solved critical problems during the early stage. As the system grew, the inventors and engineers of earlier days lost control of the system's growth. Instead, legislators made crucial decisions on standardisation and coordination and control over the direction; financiers provided capital resources that profoundly influenced the feasibility of technical activities and were capable of solving solve the critical problems associated with growth and momentum.

However, the Chinese case shows its peculiarities. China’s power system originated in a semi-colonial and semi-feudal society. It was born in wars. The imperialist invaders built the earliest power system in order to pursue economic interests and assist military expansion. The cruel realities of wars awakened the Chinese to study and pursue advanced technologies and sciences. China learned lessons from that period that a country must open up to cutting-edge ideas, technologies and countries. In this context, China’s power system grew. Educational institutions were coordinated to provide technical and scientific training. Financial and institutional innovations were promoted to correct the reverse salients.

Such a study of a socialist country and a late developer provides insight into the necessary conditions for late development. Drawing from the experiences of introducing the Western science and technology into China, building the first power network in the Nationalist era, and transferring Soviet technology to China, the Chinese case makes clear the importance of training professionals, in other words, a sufficiently large base of human capital is the necessary condition for late development. The Chinese responded to their lack of industrial professionals by adjusting and reforming schools and university departments, bringing them into line with the Western or Soviet model of higher education. The other implication of the case of China is that China adopted a globalist approach. The extension of educational openness allowed the student to learn advanced cultures and sciences and cutting-edge technologies, and the extension of economic openness created substantial opportunities for technology transfer. Chinese firms thrived on joint ventures, bringing success in the absorption and operation of advanced technology. Furthermore, China is now pushing towards frontier innovation rather than simply ‘catching up’ with developed countries.

The findings of this chapter also shed light on the ongoing green transition. If we want to achieve a green transformation, the power system needs disruptive and revolutionary changes in the technical and institutional components. The success of the green transition will require ‘values to be changed, institutions reformed, and legislation recast', because, as Thomas Parke Hughes (1983, p. 465) concluded, 'if only the technical components of a system are changed, they may snap back to earlier shape'.

The next chapter moves on to investigate the Chinese power system's ongoing green transition. It uses a neo-Gramscian framework to analyse the pathways of the local electricity industry and unpack the changing power relations of the local energy regime.

Chapter 4 The Political Economy of Local Energy Transition, Lessons from a neo-Gramscian analysis of the local electricity industry in China

4.1 Introduction

Since the Paris Agreement was reached in 2015, in which virtually all countries signed to limit the increase in global temperature above pre-industrial averages to well below 2 degrees Celsius, the need for a 'grand' transition in scale and speed towards sustainability is clear (Peter Newell & Simms, 2020; TheEconomist, 2020d). Meeting the climate change target requires an energy transition far quicker than any long-drawn-out energy transitions as we have seen in history. Thus, the pace of energy transitions is a key academic and policy question (Kern & Rogge, 2016; Peter Newell & Simms, 2020; Roberts et al., 2018).

Various lines of work provide valuable insights into how transitions occur. The Multi-Level Perspective (MLP) (Geels, 2002; Geels & Schot, 2007) is influential on studying the socio-technical transition – technological systems change in conjunction with changes in society and economy. It categorises the socio-technical changes into three analytical levels: micro-level technological niches, meso-level socio-technical regimes and macro landscape. MLP provides a crucial novel insight that a transition results from the combination and interaction of endogenous and exogenous changes on all three levels and proceeds sequentially in three phases (Geels, 2002, 2010). The earlier version of MLP was criticised by the neglect of political concerns as the government played a key role in shaping the directions and speed of energy transition (Meadowcroft, 2009; Patterson et al., 2017). In response, Geels (2014) brought politics into the analysis of the resistance against low-carbon transition by the incumbent regime. The recent work by Schot and Kanger (2018) proposed a Deep Transition framework that synthesises MLP and Perez (2002, 2013)'s Techno-Economic Paradigm (TEP); the latter builds on Schumpeter's notion of 'creative destruction' and focuses on the agents of financial and production capital and the role of government around the turning point. The Deep Transition theory seeks to explain the large-scale and long-term socio-technical changes derived from single socio-technical systems' co-evolution (Kanger & Schot, 2019; Schot & Kanger, 2018). However, such frameworks are much stronger at understanding structures than the agency, which becomes problematic regarding the urgency of the ongoing green transition demands particular attention to 'who accelerates the processes and who slows it down' (Hubert Schmitz, 2016, p. 523).

This is the question this chapter seeks to answer by focusing on the case study of China. Before answering this question, we should recognise that, first, no single actor has the capability and resources to bring about the transition. Second, within government, business and civil society, there are actors seeking to advance the green transition and actors trying to slow down the process; their motives may change, and roles may exchange during the transition. Third, transition is a phase-out and phase-in process in which the decline of incumbent industries and the rise of new ones happen simultaneously (Bromley, 2016; Fouquet, 2016; Peter Newell & Simms, 2020). Fourth, moving towards a green energy system requires much more than merely technological shifts; it is carried out in conjunction with power struggles and shifting alliances within states, markets and civil society. Thus, there has been a consistent call for applying critical political economy approaches to understand the green transition (DiMuzio & Ovadia, 2016; Kern & Markard, 2016; Peter Newell, 2019; Peter Newell et al., 2020; Paterson, 2020; Van de Graaf, Sovacool, Ghosh, Kern, & Klare, 2016). A strand of the literature suggests that attention needs to focus on the transformative alliance and the relations of power as they are essential for understanding advances and setbacks in the transition (Dong, Qi, & Spratt, 2015; Harrison & Kostka, 2014; Hess, 2014; Peter Newell, 2015; Peter Newell et al., 2020; Pearse, 2020; H. Schmitz, 2015; Hubert Schmitz, 2016). In this regard, emerging pieces of literature have explored the political economy of incumbency and explained why change is yet to occur (Peter Newell & Johnstone, 2018) and how the transition is embryonic (Baker & Burton, 2018; Baker, Newell, & Phillips, 2014). What remains to be explored is how and why progressive change does occur (Peter Newell et al., 2020, p. 3) and, more importantly, the actions at the local scale. After all, climate crises and solutions are rooted in local activities (Kuzemko, 2019). In response, this chapter applies a neo-Gramscian approach (David L. Levy & Newell, 2005; David L. Levy & Newell,

2002) to investigate the dynamic relations of power and the transformative alliances in the local energy transition process.

Drawing on Gramsci's concept of hegemony – an alignment of the dominant politico-economic groups and the moral and intellectual forces of subordinate groups (Gramsci et al., 1971; David L. Levy & Newell, 2005), this chapter analyses the dynamic hegemony-building processes in the green transition of the local Chinese electricity industry over the past 20 years. China's electricity sector is currently the single largest source of the country's carbon dioxide emission and an essential solution for reducing the total emission if paired with clean electricity. China's ambitious 30/60 goals – peak carbon emissions by 2030 and carbon neutrality by 2060 – require that it completely decarbonises its electricity industry, 60 per cent of which is still powered by dirty coal, and it accounts for half of the global coal-fired electricity (IEA, 2020b; TheEconomist, 2020b). Since the Carbon Capture and Sequestration (CCS) technology has not yet proven viable at scale (Fouquet, 2016; TheEconomist, 2020d), a rapid transition out of fossil fuels to green energy sources becomes a prerequisite for meeting the targets. Thus, this chapter focuses on the Chinese electricity industry's green transition with a particular interest in wind and solar PV power as they have been developing as a mainstream source of electricity (IEA, 2019). In line with the neo-Gramscian framework, the analysis focuses on the group of actors in a hegemonic position (i.e., the historical bloc in Gramscian terms) and look for supportive shifts within the alliance at three levels: the level of material forces of production, the discursive level, and the organisational level. The neo-Gramscian approach is helpful in unpacking the agencies and uncovering both problematic and strategic alliances that delay, push, and accelerate the power system transit towards green. It provides a theoretical framework to study how a stable coal-fired power historical bloc compromises and evolves and how a new renewable energy bloc emerges by investigating the material, discursive and organisational elements that intertwined within them.

The investigation takes the form of an in-depth case study of the electricity industry in a province located in central China, which is not rich in natural capital and heavily relies on coal but has experienced a rapid uptake of wind and solar power in recent years. It provides an ideal context to examine the power relations and understand how and why the progressive changes occur. Semi-structured interviews were conducted among various stakeholders – power generation corporations with different ownerships ranging from the state-owned (SOE) and private to township-village (TVE), electricity grid corporations, government agencies, financial institutions, and the public – at provincial, municipal and village levels, triangulated with qualitative analysis of a wide range of documents.

This study contributes to the transition studies by addressing the lack of analysis of power relations. Pearse (2020) criticises the majority of existing energy transitions research for being silent on the relations of power and calls for a framework to interpret the drivers of the energy transition. This study adopts the neo-Gramscian framework to grapple with power relations and explores the agency of coalitions in the hegemony-building process.

This research also makes original contributions to the field of political economy in two ways. First, in response to the growing plea for the political economy community to take better account of the local scale (Britton, 2018; Kuzemko, 2019; van der Ven, Bernstein, & Hoffmann, 2017), this study brings original data on the electricity sector in a Chinese province. It tackles the shortage of empirical research on China due to difficulties getting access to data (B. J. Cohen, 2014; Pang & Wang, 2013) and contains novel empirical material. Second, it offers some important insights into how and why the acceleration of transition could occur, which is a challenge the political economists now face (Peter Newell et al., 2020; Roberts et al., 2018).

This study also sheds new light on neo-Gramscian studies. It adds new empirical evidence to Western-centric neo-Gramscian studies. More importantly, it contextualises the framework in the Chinese context and distinguishes business actors into three different groups – SOE, private and TVE. The neo-Gramscian approach suffers critiques for overestimating the importance of ideology while underestimating the ‘dominant material forces’ (Burnham, 2016) and downplaying the state’s role (Bo, Böhm, & Reynolds, 2019). This study includes the business actors explicitly and the local state-business-civil society alliance at play. It problematises the re-configuration of business power in the green shift. In particular, the SOEs remain the key driver and catalyst of the rapid transition, with leverage well beyond that of the state and the public. It also highlights the missing link of finance in accelerating renewable energy deployment. Furthermore, it distinguishes the dual role of the local state – a key ally in cementing hegemony and disrupting hegemony and applies Gramsci's concept of 'integral state', which has been undervalued by the neo-Gramscians, in illustrating local states.

In this chapter, the terms ‘transition’ and ‘transformation’ are used interchangeably to mean the change from fossil fuel to renewable energy. Though there exists explicit contrast between these two terms, as has been discussed by Stirling (2015) and Hölscher, Wittmayer, and Loorbach (2018): the distinction is ‘heuristic’ (Stirling, 2015, p. 62), not mutually exclusive (Hölscher et al., 2018). The remainder of the chapter unfolds as follows. It begins by reviewing the literature on energy transitions and neo-Gramscian studies. It then introduces the empirical research context and method. This is followed by presenting the empirical findings of the changing dynamics of power relations from the analysis of the three levels of hegemony over the past two decades, outlining three transitional eras. It then discusses the transformative alliances, key factors driving the changes, and the implications of the results. It concludes with a discussion of the lessons and significance of this study on local China’s green transition to other regions and economies.

4.2 Literature review

4.2.1 Transition studies over time

Since environmental issues started to penetrate social debate in the 1970s, the energy-related industry is overwhelmingly viewed as the root of today’s most prominent environmental threat: climate change (Peter Newell & Lane, 2018; Van de Graaf et al., 2016). After the Rio Earth Summit in 1992, global warming was put on the international political agenda.[12] The revolutionary concept of

[12] One of the major results of the 1992 Earth Summit was *Agenda 21*, a dynamic programme of global partnership action calling for new strategies to invest in the future to achieve sustainable development (UN, 1992). Correspondingly, the United Nations Framework Convention on Climate Change (UNFCCC) was established at the summit and entered into force in 1994, and the Conference of Parties (COP) was created as the supreme organ of the UNFCCC. COP associates with most of the countries in the world and has met every year since 1995.

sustainable development promoted at the summit sparked lively debates within and between government and their citizens on the alternatives and new perceptions of the way we produce and consume energy (UN, 2021). Moving away from fossil fuels towards renewable energy systems has become entrenched in the energy agenda for much of the world. In the late 1990s, a multi-, inter-, and transdisciplinary research field has emerged seeking to better understand the dynamics and mechanisms of energy transitions and the role of agency herein to develop better analytical tools and governance strategies.

The initial focus of energy transition literature was on analysing transitions in socio-technical systems (Geels, 2002; Rip & Kemp, 1998; Schot & Geels, 2008). Such studies account for energy technologies as embedded in complex ‘seamless web’ (Thomas Parke Hughes, 1987) or ‘configurations that work’ (Rip & Kemp, 1998) of physical artefacts and infrastructures, natural resources, scientific and legal institutions. They emphasis the role of innovative niche technologies in driving energy transitions, focusing on how low-carbon energy technologies such as wind turbines and biofuels can be protected, developed and nurtured. However, the clean technologies did not diffuse rapidly in the noughties (IRENA et al., 2018). Smith et al. (2005) underlined that low-carbon transitions are ‘purposive transitions’ – ‘deliberately intended and pursued from the outset to reflect an explicit set of societal expectations or interests [of sustainability]’ (p. 1502). Lessons learned from the intervention-oriented Transition Management models in Dutch energy policy (Kern & Howlett, 2009; Kern & Smith, 2008; Loorbach, 2010) further underscored that radical changes in the energy system ‘require robust intervention by states’ (Smith et al., 2005, p. 1502). Correspondingly, several scholars critiqued the neglect of political concerns in the fast developed socio-technical transition literature and argued for the indispensable role of the state in shaping the directions and speed of energy transitions (Meadowcroft, 2005, 2009; Patterson et al., 2017). In response, there have been some advances in this regard with a shifted attention towards the ‘regime resistance’ and ‘destabilisation’ of fossil fuel regimes (Baker et al., 2014; Geels, 2014; Turnheim & Geels, 2012, 2013). Such analysis takes into account the political dynamics of the fossil fuel regimes, highlighting the institutional ‘inertia’, ‘carbon lock-in’ (Unruh, 2000) or ‘path dependency’

(Arthur, 1989) and the relative powers of incumbent interests to sustain the incumbent energy pathways.

Meanwhile, there is a growing interest in the broader politics of green transformation (Scoones et al., 2015). A real spike in interest in the ongoing energy transitions within the field of political economy appeared after the ratification of the Paris Agreement in 2015. The obligations contained in Paris Agreement, together with the earlier published Fifth Assessment Report by Intergovernmental Panel on Climate Change (IPCC) in 2014, show that rapid transitions from fossil fuels towards renewables offer the only chance of keeping global warming within 1.5 or 2 degrees Celsius limit (IPCC, 2014; UNFCCC, 2015). After the Paris Conference, most of the countries in the world submitted their (intended) Nationally Determined Contributions (NDCs) detailing their commitments to climate mitigation and adaptation for the post-2020 period. Such efforts demonstrate global commitment to sustainable transitions for the first time, thereby signalling the required political will to foster quick transitions and overcome resistance. The climate emergency stimulated a debate on the speed of energy transition in academia (Fouquet, 2016; Grubler, Wilson, & Nemet, 2016; Kern & Rogge, 2016; Sovacool, 2016). Studying the historical transition from biomass to coal, coal to oil or oil to gas, they conclude that the ongoing energy transition could occur faster than was the case for historical transitions because it is 'consciously governed' (Kern & Rogge, 2016, p. 13). Urgency and purposiveness further heightened the 'political nature' of the green transformation (Kern & Markard, 2016; Kern & Rogge, 2016; Scoones et al., 2015). Proposals for incorporating political economy themes into energy transition studies, emphasising accelerating transitions, have been put forward (Roberts et al., 2018; H. Schmitz & Scoones, 2015). Consequently, a few pieces of studies emerged considering the political economy dimension.

Johnstone and Newell (2018) highlight that 'addressing who the state serves and which interests it seeks to protect is vital to assessing the prospects of more radical and progressive interventions imagined in much transition scholarships' (p. 78). Their investigation of different dimensions of state power has widened the analytical lens in transition studies by incorporating and analysing multiple and diffuse forms of state power. Notably, it underscores actors being 'street-level bureaucrats' (Lipsky, 2010) whom the state seeks to steer and align. This is closely related to a strand of academic enquiry on the incumbency. Peter Newell and Johnstone (2018)'s study on fossil fuel subsidiaries has turned the spotlight on the fossil fuel corporations and linked to the studies on transnational corporate power in the politics of global warming (David L. Levy & Egan, 2003; David L. Levy & Newell, 2005; Peter Newell & Paterson, 1998; Wright & Nyberg, 2014). A common theme from these studies is 'political coalition' (Hess, 2014), spanning across government institutions and industry and forming powerful pressure groups that influence national and international policy alike.

With developing countries' full engagement and commitment in the battle of climate change in the Paris Agreement, there is growing interest in empirical studies of developing countries after 2015. Power et al. (2016) focus on the impacts of rising powers, like China, India and Brazil, as development donors on the energy transition of two Southern-Africa countries. Drawing on the literature on socio-technical transitions, South-South cooperation and energy geographies, they illustrate how countries' policy autonomy and developmental space to pursue their goals in the energy sector can be circumscribed by their dependence on aid or trade relations with more powerful public and private actors. Hubert Schmitz (2016) applies a political coalition perspective to explore who drove the formulation and implementation of climate-relevant policies in four developing countries. He emphasises that the 'political coalition' perspective, which is often used in the analysis of incumbency, is 'equally important for understanding the opposing forces' (p. 525). He takes into account different types of actors from government, business and civil society who operate at different levels and pays attention to 'alignments of interests' across them. The findings show that alliances are critical, and the motives for supporting low-carbon policies vary, but climate change mitigation is often not the primary concern. Schmitz's study provides a stepping-stone for research on the political feasibility of low-carbon transformations.

Turning to the research on China's energy transition, studies tend to be either technology-focused (Gallagher, 2014; Lewis, 2013b) or policy-focused (Andrews-Speed, 2016; Andrews-Speed & Zhang, 2019; L. Brandt & Rawski, 2019). Indeed, China has witnessed a rapid development of renewable technologies, especially its wind turbine and solar panel sectors have grown at a stunning speed and outpaced most of the leading industrial countries. Such marvellous achievement is often credited to China's distinctive 'state-led model' – a top-down policy process with little stakeholders' participation (Engels, 2018; Shen & Xie, 2018), which is also often labelled as 'developmental state' (G. C. Chen & Lees, 2016) or 'authoritarian environmentalism' (B. Gilley, 2012; M. A. Schreurs, 2011). However, some thought-provoking studies have challenged such a state-centred perspective by arguing that the growing importance of non-state actors, particularly business actors, are gaining prominence in the low-carbon energy transition process (Dai, 2015; Shen, 2017; Shen & Xie, 2018). Shen (2016, 2017) focused on the role of leading industrial corporations in the policymaking stages. Dai (2015) explored the under-researched renewable energy policy implementation stage. Shen and Xie (2018) investigated the internal power dynamics within the renewable energy sectors and their relations with fossil fuel segments. Together these studies provide important insights into the state-business dynamics and indicate that local business, particularly the centrally owned SOEs, is the key actor in addressing climate change. The findings also consistently point to 'implementation gaps' (Eaton & Kostka, 2014; Ran Ran, 2013; R. Ran, 2017), a well-known Chinese phenomenon resulting from the divergence between the priorities of the central and local government, and suggest centrally owned SOEs have played a major role in 'synergising the interest-gap between central and local officers' (Shen, 2017, p. 93). These studies also suggest a pertinent role for the state-business alliance – an 'informal coalition' (Harrison & Kostka, 2014) – to promote renewable energy sectors. Shen and Xie (2018) further argue that the interest-based alliance in the early years is falling apart and advocate a value-based alliance.

So far, these China studies have clearly indicated the importance of state-business and central-local relations in understanding the rise of renewable energy sectors. The urgency for swift energy transitions has opened a vast research agenda. There remained too little research on the varying roles a variety of actors would need to play to make the rapid transition happen. Existing studies remain narrow in focus dealing only with state-business relations. However, the ongoing transition is both 'top-down' involving the elite alliance between states and business and 'bottom-up', pushed by grassroots innovators and entrepreneurs and part of broader mobilisations among civil society (Scoones et al., 2015). Borrowed insights from the rich literature in the environmental governance realm, more actors, including mass media (Ma, Webber, & Finlayson, 2009; Tong, 2014, 2015; Q.-J. Wang, 2005; G. Yang, 2010), public participation (Guo & Bai, 2019; Mu, 2018; Munro, 2014; G. Zhang, Deng, Mou, Zhang, & Chen, 2019; L. Zhang, Mol, & He, 2016), NGOs and research institutions (Ho, 2001; H. Huang, Sheng, & Barg, 2017; W. Li, Liu, & Li, 2012) and financial institutions (Liao & Shi, 2018; Mol, 2017), are involved and increasing their influence in China in addressing climate issues. Thus, this chapter takes into account multiple stakeholders and traces how the changing balance of power of different actors might lead to radical changes. Unlike the existing literature exclusively focusing on the leading companies, central SOEs in particular, this study also investigates the role of local private firms and rural TVEs in the local energy transition. TVEs have nonstandard ownership, being neither state-owned nor private owned, and are controlled by the local community (i.e. township or village) government (Qian, 2003). Also, the empirical evidence in the reviewed studies is based on city-level field investigations carried out before 2015. More updated evidence is needed as impressive acceleration in renewable deployment happened after 2015 (IEA, 2018). In 2017, two-thirds of growth in China's total installed power generation capacity came from renewables, wind and solar PV in particular (IEA, 2019). How does the rapid uptake of renewables happen? This chapter adds new evidence for the acceleration stage of the energy transition. Moreover, this study conducts field investigations across the provincial, city, and village levels to better understand the local energy transition.

In all the studies reviewed here, coalition (or alliance) becomes the central concept in both West and China, albeit with a different focus of the investigation. While studies in Western contexts focus on the coalitions against the green transition, Chinese studies are more concerned with alliances supporting the change. Bringing about transitions requires resources of different types, such as expertise, money, organisational capacity, and legitimacy and leadership, which are distributed over a range of actors in government, business, and civil society (H. Schmitz, 2015). Accelerating the process can come from the alliance between these actors (ibid). It is, therefore, useful to concentrate on the transformative alliance, not just who could be considered a member of such an alliance, but also how it is formulated. Moreover, the green transition is a process rather than an end-state (Scoones et al., 2015) involving complex and dynamic social relations. The changing relations of power shapes different pathways. Thus, we need a theoretical framework with enough scope for actors and the processes, compared with the leading transition theories that overemphasise structural development falls short of a theoretical basis to reflect the social relations and the power relations that lie therein (Haas, 2019). In doing so, this chapter applies a neo-Gramscian framework to conduct the empirical investigation of the ongoing energy transition.

4.2.2 Neo-Gramscian framework in the era of climate change

The neo-Gramscian perspective could be traced back to the pioneering work of Robert W. Cox (1981, 1983), who mobilises Antonio Gramsci's analysis of hegemony to study power structures within the global political economy. Relying on Gramsci's insight that hegemony incorporates both force and consent, Cox argues that hegemony comprises more than material forces and is 'based on a coherent conjunction or fit between a configuration of material power, the prevalent collective image of world order (including certain norms) and a set of institutions which administer the order with a certain semblance of universality' (Cox, 1981, p. 139). By conceptualising hegemony as a fit between material power, ideas, and institutions, the neo-Gramscian perspective has advanced the state-centric International Relations (IR) theories and contributed to the development of critical (international) political economy theory since the 1980s (Budd, 2013; Hopf, 2013).

Since the beginning of the 21st century, the neo-Gramscian framework has been applied to global environmental governance research, with influential works by David L. Levy and Newell (2002) and David L. Levy and Egan (2003). They introduce a neo-Gramscian approach to international environmental politics to extend the overly state-centric IR approaches to better account for the important role of non-state actors, especially business and NGOs, in environmental politics and governance (David L. Levy & Newell, 2002, pp. 85-86). They also recognise that the existing management and corporate political strategy approaches 'tend to be decontextualised from the wider relations of power' (David L. Levy & Newell, 2005, p. 57) and suggest a political economy perspective to enrich institutional theory (David L. Levy & Egan, 2003).[13] Thus, they propose a critical neo-Gramscian approach to bridge IR theories at the macro level and the management and organisation theories at the micro-level (David L. Levy & Newell, 2005, p. 47; David L. Levy & Newell, 2002, p. 84). In doing so, they apply Gramsci's conception of hegemony, also drawing on insights of neo-Gramscian studies in the field of IR, to understand the assemblage of political, economic and discursive struggles in environmental governance. They argue that the establishment of hegemony in the Gramscian framework resembles the process of field stabilisation in institutional theory, while the former emphasises pressures for 'convergence and stability' and the latter highlights 'disequilibrium and change' (David L. Levy & Newell, 2002, p. 94). Their analysis pays attention to the organisational, economic, and ideological pillars of powers to illustrate the 'process of coalition building, conflict, and accommodation that drive social change' (David L. Levy & Egan, 2003, p. 803). Following their neo-Gramscian approach, a strand of studies has emerged to address the ability of non-state actors, including corporations (Kourula & Delalieux, 2016; D. Levy, Reinecke, & Manning, 2016; Maielli, 2015; Nyberg, Spicer, & Wright, 2013; Nyberg et al., 2018), NGOs and social movements (Andrée, 2011; Girei, 2016; MacKay & Munro, 2012; van Bommel & Spicer, 2011), to outmanoeuvre their rivals over environmental contestations and negotiation.

The upshot of using a neo-Gramscian framework is that it can bring to light the complexity of the processes of coercion, consent, and resistance involved in large-scale social change (Andrée, 2011, p. 187) through an analysis of three sets of relations of power – the material, institutional and discursive. Energy transitions are contested processes involving a range of actors across government, business, and civil society (Pearse, 2020). Thus, the neo-Gramscian framework could offer a theoretical tool to interpret these processes, particularly concerning various actors' changing power relations and strategies on energy. Also, the neo-Gramscian analysis 'serves to highlight vulnerabilities, weak spots and active agents of change' (Peter Newell, 2019, p. 43), which

[13] More connections with institutional theories see David L. Levy and Scully (2007) and Maielli (2015).

would provide a source of clues to steer and further accelerate the ongoing green transition. In addition, the neo-Gramscians, in line with the transition scholars mentioned above, also contend that the establishment of a 'historical bloc' requires continuous work in forming 'strategic alliances' (Nyberg et al., 2018, p. 237). At the same time, the neo-Gramscian perspective, as Gramsci's definition of historical bloc indicates, further puts forth that such alliances entail not only various social groupings but also 'the specific alignment of material, organisational and discursive formations which stabilise and reproduce relations of production and meanings' (David L. Levy & Newell, 2002, p. 87).

Applying the neo-Gramscian analysis in transition studies, this chapter, in line with previous neo-Gramscian studies, argues that the Gramscian notion of hegemony and the historical bloc is particularly relevant. David L. Levy and Egan (2003) have used the concept of hegemony to explain the fossil fuel industry's ability to preserve its dominance. They outlined three sets of strategies the American and European automobile and oil industries employed to preserve their hegemonic position and expand their political influence over climate change policies. Such strategies are discursive strategies, for example, questioning climate science; organisational strategies in building associations and lobbying regulatory agencies to counter regulatory challenges; and economic strategies such as industry consolidation and even investment in reducing greenhouse gas emissions. Nyberg et al. (2018) also explain how the British fossil fuel industry reproduced its hegemony by linking local benefits to national or global interests such as local employment, national energy security and global emission reduction and established an alliance to produce social consent through the articulation of identities and interests. Both studies recognise the long-lasting fossil-fuel hegemony and the mechanisms through which this hegemony is produced; while the former shows how the fossil fuel hegemony, also termed as the 'fossil fuel historical bloc' (Phelan, Henderson-Sellers, & Taplin, 2013), could accommodate threats through compromise and concession when confronted with challenges,[14] the latter explains how diverse and often competing interests, identities and demands are discursively constructed as

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[14] More studies that explain the reciprocal stability of hegemony could refer to D. Levy et al. (2016), and Kourula and Delalieux (2016).

common sense.[15] However, they fall short of indicating how ‘counter-hegemonic sustainability forces’, that is the renewable energy sector, could outmanoeuvre the fossil-fuel historical bloc’s hegemonic dominance, and so that a ‘just sustainability hegemony’ will in place of the current fossil fuel historic bloc (Phelan et al., 2013). This chapter seeks to develop an understanding of this issue by examining the dynamic hegemony building and contestation processes.

The existing neo-Gramscian perspective also suffers critiques for overestimating the importance of ideology, focusing more on the discursive dynamics in the construction of hegemony and downplaying material forces (Burnham, 2016). It is also being criticised for ‘a theory of the state redundant’ (Burnham, 2016, p. 88) with relative neglect of the coercive aspects of the state (Budd, 2013, p. 28). This study considers the three elements together to assess supportive shifts within the relations of force at the material, discursive and organisational levels. This study also gives an account of the local state. However, in the Chinese context, it is problematic regarding the relation between the local state, business and civil society. The demarcation between local state and business is vague. In China’s regionally decentralised authoritarian system, much of the business of government has been delegated to sub-national levels (Kostka, 2014; Kostka & Nahm, 2017). Local governments are responsible for providing public services, enforcing laws and regulations, and implementing national legislation (Kostka & Nahm, 2017). Local governments rely on enterprises, particularly those large firms or SOEs, to fund government programmes, provide employment and bolster tax revenues. SOEs, particularly the state-owned utilities, are the key policy actors (Leutert, 2018; Shen, 2017), often being seen as the ‘arm of the state’ (L. Jones & Zou, 2017); on the other hand, SOEs are essentially autonomous and market-driven actors (Sheng & Zhao, 2012). The relationship becomes more complicated when it comes to the ‘fuzzy’ rural TVEs (Weitzman & Xu, 1994). With reference to the Law on Township and Village Enterprises of 1996, TVEs are ‘economic units which are either collectively owned by local residents in the rural areas of China or mainly owned and controlled by the peasants’ (Fu & Balasubramanyam, 2003, p. 28). This chapter

[15] More studies on the discursive construction of interests could be found in David L. Levy and Spicer (2013), Nyberg et al. (2013), and van Bommel and Spicer (2011).

focuses on the collectively-owned TVEs,[16] which are the property of residents in rural communities and managed by the township and village governments (Fu & Balasubramanyam, 2003; Weitzman & Xu, 1994), as they are more relevant to the study of the local electricity industry. The leaders of the rural community government act as entrepreneurs. Taken all together, this chapter argues that the local state resembles Gramsci's notion of 'integral state', formulated as 'State=political society + civil society' (Gramsci, 1999, p. 532), which is rarely mentioned in the existing neo-Gramscian studies. This study contributes to the neo-Gramscian framework by extending the analysis of state-business-civil society and their interplays through incorporating the analysis of diverse types of business in China and investigating the 'omnipresent' local state at provincial, municipal and county levels.

There also exist empirical gaps in the existing neo-Gramscian literature, including the neglect of localities (Dauvergne, 2005) and a paucity of research in non-western contexts (Bo et al., 2019). This study, therefore, goes beyond western-centric neo-Gramscian studies to include the non-Western context and locates the empirical investigation within a local area, adding new empirical evidence to the neo-Gramscian research.

4.3 Methodology

4.3.1 Research context

This explorative study, in line with an inductive focus, employs a qualitative case study approach to investigate how the interplays between local government, electric corporations, banks, and the general public have shaped the evolving dynamic processes of political and economic leverage over the green transition, as well as the key driving forces in the dynamic hegemon-building processes. The case study was recognised as an appropriate method of empirical inquiry because the research aimed at investigating 'a phenomenon in depth and within its real-world context' (Yin, 2018, p. 4).

[16] More detailed classification of the TVEs could be seen in Fu and Balasubramanyam (2003). TVEs were China's growth engine in the 1990s (Qian, 2003), among which the collectively-owned TVEs continue to play an essential role in the economic development of rural areas, especially in the solar power sector (NDRC & NEA, 2016c; F. Zhao, Li, & Zheng, 2016).

The case study was conducted in a province located in central China. Due to the assurance of confidentiality for all participants, this province was coded C-province. The main criterion for the selection of this province was the fact that access to the region was made easy by prior personal contact. C-province has a high population density with scarce resource endowment and high industrial and agricultural activity and is one of China's most polluted provinces. Coal is the dominant source of generating electricity accounting for more than 80 per cent of the total power generation, and state-owned power generation firms (SOEs)[17] dominate, accounting for 80 per cent of the whole electric market. However, there has been a spectacular growth in wind and solar PV power since 2015, see Figure 4-1. It is representative of regions with limited renewable resources, which have struggled to seek ways to improve their energy structure.

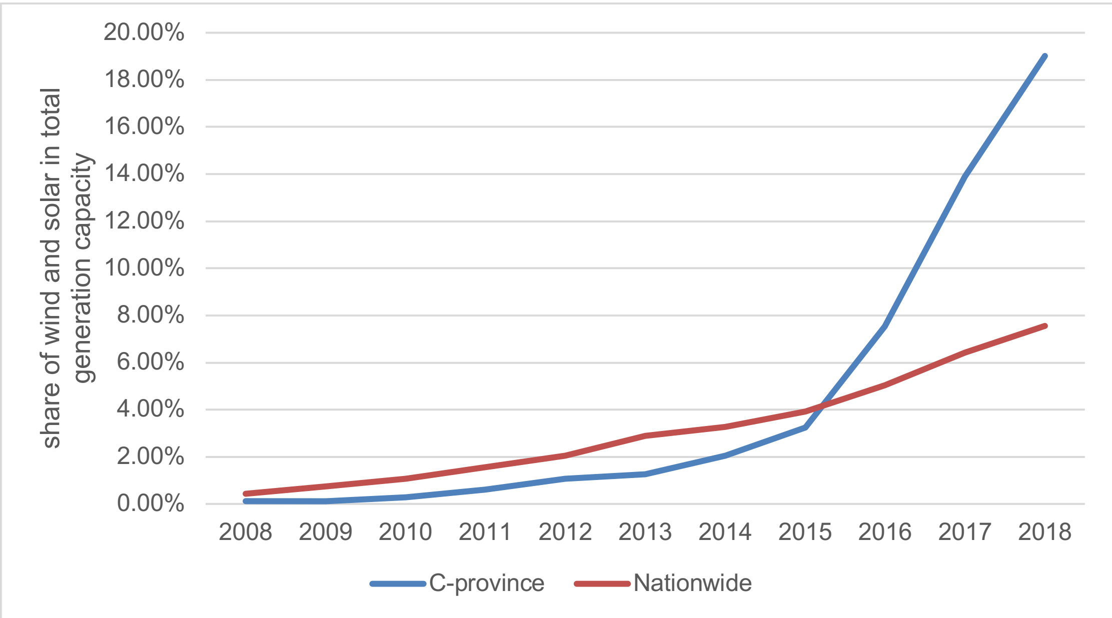

Figure 4-1 Share of electricity generated by wind and solar power (%)

Source: nationwide data from IEA database; provincial data from NEA

Then a city-level field investigation is conducted in three cities. City1 is a major industrial base and has the region's largest coal-fired power fleet with two subcritical units, two supercritical (SC) units and one ultra-supercritical (USC) unit; meanwhile, it shares the largest portion of the province's total wind-power

[17] SOEs in this study are those classified by State-owned Assets Supervision and Administration Commission of the State Council (SASAC) and listed in http://en.sasac.gov.cn/directorynames.html.

capacity. City2 and city3 are adjacent cities and located on the plain area without coal or abundant renewable energy sources; while city2 is a pioneer in developing large scale low-speed plain wind farms, city3 has the region's first large-scale solar PV plant. They were chosen because a rapid take-up of renewables has been happening, albeit mainly driven by different business actors. SOEs dominate city1's power sector, private firms are the pioneer investors in city2's renewable energy projects, and TVEs prevail in the rural communities in city3. Given these differences, this chapter focuses on drawing lessons from these three cities rather than directly comparing them.

4.3.2 Data collection

Data were drawn from multiple sources: in-depth interviews triangulated with a wide range of documentary data. Semi-structured interviews were conducted with the relevant stakeholders. Residents were randomly picked and interviewed. The other interview subjects, working at either provincial, city, or county level, fall into three broad categories: government authorities, managers from electricity generation and grid companies, and employees from local commercial banks working on energy-related projects. Most of the interviewees have worked closely related to the energy industry for more than ten years and have witnessed and participated in the local power industry transition. Each interview lasted 45 minutes to 1.5 hours and was audio-recorded with permission and then transcribed and translated into English. Snowball sampling methods were used to ensure that no important stakeholders were left out.

Three rounds of in-depth interviews were conducted between 2018 and early 2021. The first round of interviews was carried out at the provincial level, including six state-owned electricity generation firms, two government authorities working in the provincial National Development and Reform Commission (NDRC), two managers in a commercial bank. The participants in the second phase were identified through the snowball technique. The managers in provincial level firms recommended their power plants located in the three cities. The provincial authorities referred municipal authorities and city-grid firms, and the municipal government then introduced the private firms and TVEs. The participants from commercial banks at the provincial level also recommended their colleagues at the city level. At the end of the second round of field investigation, I visited ten state-owned power plants, six private power plants, two TVEs, three municipal governments, one grid firm, and three banks and interviewed nine residents face-to-face.[18] The final round of interviews included follow-up interviews, mainly over the telephone, in the summer of 2020 to seek answers to questions that emerged from previous interviews and in the summer of 2021 to track the new progress or changes in the local energy transition.[19] Appendix E provides an overview of the interview procedures and the collected data.

Interviews were triangulated through a qualitative analysis of various documentary data, including China's National Climate Change Program (2007 to 2010), China's Policies and Actions for Addressing Climate Change (2011-2017), Five-Year-Plan of Energy Development at both state-level and provincial level, Five-Year-Plan for the Electricity Sector at both state-level and provincial level, environmental and energy-related documents issued by the provincial government;[20] industrial reports and datasets: China Electricity Council Yearbook (2006-2017), National Bureau of Statistics and IEA database; corporate operating and financial data provided by some of the electric firms; Guidelines on Due Diligence in the Credit Granting to Electric Enterprises (2007-2017) provided by local commercial banks; and relevant media articles published local official and social media portals. In addition to interviews, other oral evidence was collected from a series of television interviews about carbon-neutral/climate change produced by the China Central Television (CCTV2) programme *Dialogue* in 2021 and informal conversations with keynote speakers[21] from seminars on climate

[18] Residents were randomly picked. Generally, I started conversations with the residents who lived or worked near the power plants I visited. Only nine of the dozens of residents I met agreed to be interviewed. However, compared with the interviews with participants from the company, bank and government that usually last more than 45 minutes, the conversations with residents lasted 20 minutes on average.

[19] The follow-up interview was initiated in the summer of 2020. Only five original interviewees agreed to be interviewed via telephone, and others preferred to meet face-to-face. In 2021, when I was able to travel to China, I contacted the original participants. Some informants from the bank and government agreed to be re-interviewed in person, while those working in the industry declined to take further interviews in any form.

[20] All the provincial documents were sourced from the local NDRC website and the local Department of Ecology and Environment website.

[21] The keynote speakers are the engineers on clean technologies, chief policymakers on climate issues, and senior analysts in the leading consulting firms.

change held by the headquarters of two Chinese banks in August and September 2021.

4.3.3 Data analysis

4.3.3.1 Preliminary analysis

Data collection and analysis were carried out simultaneously. Each interview was recorded through both audio-recording and notetaking. After each interview, a fieldnote was written up, summarising the key concepts raised by the informants and highlighting the emergent issues of interest, which were then followed up at subsequent interviews. Such early analysis enabled me to reformulate interview questions, locate the relevant documentary materials and refine the inferences to be drawn as the interview continued. After completing all interviews and sorting out all the field notes and interview transcripts, sources were evaluated critically.

4.3.3.2 Source criticism

Prior to analysing both oral and written evidence in depth, sources were evaluated critically in terms of reliability and validity. The reason for conducting source criticism is to help address the problems with data reliability in China. Both the external and internal critiques of the data were included to establish authenticity: the external critique serves for the validity of evidence, and the internal criticism constitutes the reliability of data sources (Lundy, 2008). The process started with external criticism in which the authenticity of documents was evaluated. Following the criteria proposed by Gottschalk (1950) and Howell and Prevenier (2001), I considered that the document was more authentic as they were written for the sole purpose of making a record, like corporate operating and financial data; for internal communications, such as unpublished local government documents and local policies issued by commercial banks; for making public records, such as government policies and electronic databases; and the authority of the author, for instance, the industrial reports issued by China Electricity Council which is recognised authority.

After verifying the written documents, the oral evidence was critically evaluated for its credibility and internal consistency (Thompson & Bornat, 2017, pp. 363-

364). All the participants from the utilities, except one informant from TVEs and one manager from a private generator,[22] have been working in the electricity industry for at least ten years. Interviewees from the government and commercial banks have been involved in the business of electricity for more than ten years. They are able to provide reliable information. The oral evidence seemed reasonably credible. However, their testimonies were partial as participants in different positions could only see parts of the whole story and came to conclusions based on what they experienced, and their views were biased to some extent because they had different backgrounds and treated the same problems from their own separate angles. However, it did not mean that they were incorrect. ‘No source is without bias – it can actually be very informative’, Arnold (2000, p. 58). Thus, such information from the interviews was not discarded; rather, the partial and biased answers were checked against one another as triangulation and then combined to form the narrative with knowledge derived from other sources.

During the evaluation process, sources were cross-checked: interviews from the same locality were cross-checked with each other, details were compared with the manuscript and printed sources, and documents were tested for their consistency with other documents originating in the same period (Evans, 2000; Thompson & Bornat, 2017). When written and oral evidence diverged, it did not mean one account was necessarily more reliable than another. As Thompson and Bornat (2017) suggest, ‘the divergency may present two perfectly valid accounts from different standpoints, which together provide vital clues towards the true interpretations’ (p. 364).

4.3.3.3 Thematic analysis and synthesis

After the sources were critically evaluated, a thematic analysis of the interview data and documentary material started, through which qualitative data are segmented, categorised, summarised, and reconstructed to capture the crucial concepts within the data set (Ayres, 2008). Firstly, I conducted a more detailed

[22] The interviewee managing a TVE was also a director of the township government. He was a university student village official who graduated from a well-known university with a degree in engineering and worked in the village for three years. The informant from a private generator has worked in the power industry for six years, and he was quickly promoted to regional manager because of his professionalism.

and fine-grained analysis of interview transcripts. The first round of interviews conducted at the provincial level was analysed firstly. The participants were decision-makers and mastered the overall pictures and plans of the energy transition in the region, and therefore they were asked relatively general and comprehensive questions and could provide information and statement at a high level. Specific words and sentences that repeated frequently or sounded different from the ordinary vocabulary were labelled, together with the emergent themes aroused from the preliminary analysis generated themes. Then commonalities and differences of causes and consequences were located through constant comparisons. The next step was reviewing and examining initial themes and finding additional and new ideas. In this step, the second-round interviews were evaluated, triangulated with the documentary materials and the third-round interviews to support the analysis and verify the findings.

To fully comprehend the changing story over the past 20 years, I organised the emergent themes in chronological order, accounting for the changes in the major actors' involvement in the local energy transition (see Table 4-1). While creating the chronological map, I realised that the green transition process was characterised by two main turning points: 2013 and 2015. Since 1997, the electricity industry has undergone constant reforms aiming to decentralise the industry and vitalise the electricity market (see Chapter 2 and Appendix C). Nearly all the interviewees from government and business mentioned that the top priority in the noughties was ensuring reliable power supplies and the coal-fired power sector had a golden decade. Despite a series of regulations and initiatives on enhancing energy efficiency, lowering emissions, and promoting renewable energy development, they all concentrated on building advanced coal power plants. In 2013, both the local government and business sensed the significant change in the industry when Xi Jinping became the supreme leader of the country who showed the new government's determination to curb air pollution and clean the energy industry. Since 2015, the government, businesses, and citizens have all acknowledged that shifting towards renewable energies is an irreversible path, coinciding with the significant turning point in the curve in Figure 4-1. Therefore, I grouped all the themes into three eras: coal-fired power bloc (1997-2013), contesting coal-fired power hegemony (2013-2015), re-organising hegemony (2015 to present), and then sorted them according to the neo-Gramscian framework by categorising them into three elements – organisational, material, and discursive (see Table 4-2).

At the end of the data analysis, I recognised the changing themes of the energy transition process and abstracted the themes as the main hegemony-building processes. I further visualised the dynamics among the actors, as shown in Figure 4-2, presenting the changing relations of power in the process of hegemony-building in three eras. Based on Table 4-2 and Figure 4-2, the following section discusses the changing power relations and the material, discursive and organisational elements that intertwined within them in the local energy transition over the past two decades.

		Coal-fired power sector					Renewable energy sector				
	Regulations/Events	SOE	Private enterprise	Local Government	Bank	Civil society	SOE	Private enterprise	Local Government	Bank	Civil society
1997	Decentralization; Electricity Power Law	Co-existence		Support expansion of coal-fired power sector	Support SOEs						
1998											
1999											
2000											
2001											
2002	Further decentralization of power industry	Rapid expansion	Stable growth								
2003											
2004											
2005	Renewable Energy Law										
2006	Medium and Long-term Plan for Science and Technology										
2007	Energy efficiency		Closing down								
2008	Global financial crisis; Extreme weather										
2009	Coal price increase (2009-2011); Amendment of Renewable Energy Law	Financial loss					Wind power plants	Solar PV manufacturers			
2010											
2011	EU&US Embargos against Chinese Solar PV manufacturers (2011-2012)										

2012	SASAC & Ministry of Finance provided direct cash injection of Big Five thermal generators; Coal price decrease							Bankruptcy of manufacturers	Support the development of solar PV power farms		
2013	The outbreak of air pollution; Feed-in tariffs for wind and solar power; Establishment of the renewable energy fund	Retrofitting; Low load factor; Installation of the monitoring system; profitable				Public awareness of environmental pollution		Solar PV power farm			
2014	Recentralization; Anti-corruption; Energy efficiency;										
2015	Relax the need for central government approval for infrastructure projects; New environmental Law; Paris Agreement; Solar PV Poverty Alleviation initiative				Stopped providing loans to coal-fired power plants	The release of the documentary Under the Dome; Public outrage on air pollution		Solar PV power farms; Low-speed wind farms	Pursuing the national experimental site of low-speed wind technology; TVEs on solar PV power	Support SOE's large scale wind power farms and Solar PV for Poverty Alleviation projects	Job-creation; recognised the economic benefits of local renewable energy power plants
2016	Coal price soared; SOE reform; 'Build china into a science and technology giant'	Financial loss		Environmental supervision			Solar PV and Wind power plants				
2017	'Beautiful China' blueprint										

Table 4-1 Changes in the electricity industry grouped by actors

	Coal-fired power historical bloc, 1997-2013	Contesting coal-fired power hegemony, 2013-2015	Re-organizing hegemony, 2015 to present
Organizational level	Decentralisation of local government; First round of Electricity Industry Reform: decentralisation of generation sector; Cadre rotation and performance evaluation schemes Indigenous innovation; Energy efficiency	Recentralisation of local supervision; Creation of Central Environmental Protection Supervision Team; Anti-corruption initiative; Local government-private ties; Introduction of renewable energy quota system; EIA agency	Global commitment on decarbonisation; Second round of Electricity Industry Reform: decentralisation of generation and supply sectors; Technological self-reliance; SOE reform; SOE’s Acquisition of green entrepreneurs; Solar PV for Poverty Alleviation initiatives; Green TVEs
Material level	Advanced Clean coal technology; Reasonable coal price	Bankruptcy of local solar PV manufacturers; Monitoring technology; Advanced social media technology; Feed-in-tariffs & renewable energy fund Resistance: infrastructure lock-in	Financial support from the commercial banks on renewable power plants (prefer SOE); Increased coal price (coal impasse); Advanced and cost competitive renewable generation technologies; Low-speed wind technology; Withdrawal of financial supports on coal-fired power projects from commercial banks; Energy storage technology
Discursive level	‘Common sense’: ‘coal is the vital essence of better life’; Weak environmentalism	Awakening environmentalism; Market share; Job stabilisation	Climate crisis; Renewable is profitable; SOEs: from producing for the public to making money for the public; Job creation; Education on green technologies

Table 4-2 Shifts within the alliance at three levels

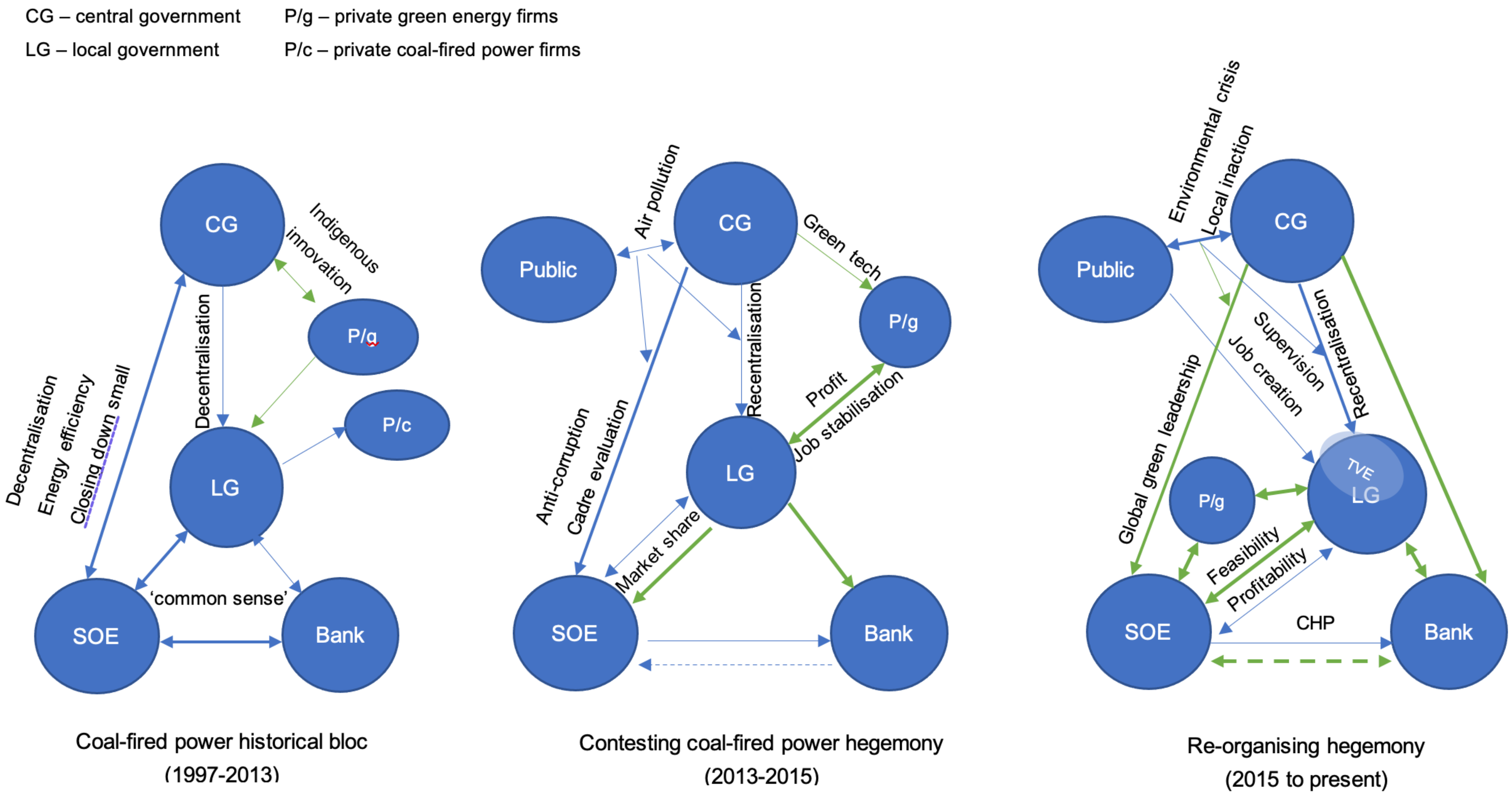

Figure 4-2 Relations of power in hegemony building

4.4 Findings

The findings reveal the evolution of the local electricity industry on three levels: the level of material forces of production, the discursive level, and the organisational level. Table 4-2 shows the mechanisms for forming and weakening the coal-fired power historical blocs and the emergence and fast penetration of renewable energy generators. Figure 4-2 highlights who has constituted historical blocs in each period to promote changes and the forces driving action of the relevant actors. The arrows in Figure 4-2 show the interaction between each actor, where the green ones represent the green actions regarding the development of renewable energy power plants and the bold arrows mean stronger relationships.

4.4.1 Strong coal-fired power historical bloc (1997-2013)

Like its neighbours in central China, C-province lagged behind its counterparts along the coastal area. It was not until the mid-1990s that C-province realised its first boost by adjusting its industrial structure and establishing a heavy-industry development system with coal as its core. Since then, the increasing centrality of coal to economic growth has led to a solid societal commitment to coal-based economic growth, which constructed a coal-fired power historical bloc.

On the organisational level, China’s market reforms over the 1980s and 1990s delegated the provincial government more autonomy to pursue economic policy according to local conditions and objectives. To combat massive electricity shortages at that time, provincial governments and local enterprises increasingly shared planning roles with the central bureaucracy. Following the issuance of the Electricity Power Law in 1997, which aimed to decentralise the power industry, the sector was restructured. Local governments retain an essential role in planning and operation through the annual generation plan allocation, which is credited with increasing local tax revenues and bolstering local economic growth. Because of the rapid growth of the local economy due to the vigorous promotion of thermal power construction in the late 1990s, the then provincial leader got promoted quickly and became a member of the Chinese Communist Party (CCP)’s Central Committee. Following his political triumph, his successors further pushed the development of heavy industries. In C-province’s 10th and

11th Five-Year Plan (2000-2010) of the energy and electricity development, promoting the development of coal-fired power plants was at the centre of the plan, and such task was assigned to the municipal governments. Local directors who actively developed large-scale (above 300MW) coal-fired power plants had more chance of advancement than their peers who invested in renewables (Interviewee G1 & G3, December 2018). From 2005 to 2011, provincial leaders regularly met with managers from the electric SOEs and expressed their determination to build a national thermal power base.[23]

Meanwhile, the electricity reform in 2002 unbundled the country's electricity generation assets into five large SOEs. The newly established central SOEs rushed into the market, actively investing in coal-fired power plants to seize market shares in the region. As the central state's 10th and 11th Five-Year Plan consistently highlighted the importance of energy efficiency and self-sufficiency, a massive industrial upgrading mandate was rolled out to shut down small coal-fired power plants and replace them with larger, more efficient units. The process started in 2000 and accelerated after former President Hu Jintao incorporated the concept of Circular Economy, which underlined principles of reduction, reuse, and recycling in industrial investment and development, as the state's development strategy in the 11th Five-Year Plan (2006-2010). Consequently, those small-scale, privately owned coal-fired power plants were forced to shut down. The central SOEs further consolidated their leading position in the region's power market by building large, advanced coal-fired power plants. On the bank's side, in 2007 and 2008, the financial system introduced policies on green insurance, green securities, and green credits, marking the official launch of China's green finance policy. The local bank started to issue its guidance on financing the power generation industry. The annual released guidance (2007 to 2014) all showed the bank's willingness to grant loans to thermal power companies with the preference of SOEs. Together with the strong support from the local government and the banks, the average growth rate of the total capacity of thermal power generation kept at 10 per cent from 1997 to 2013 and the total capacity of thermal power generation peaked by 2013 (see

[23] Information provided by interviewees from the SOEs and cross-referenced from local newspapers.

Appendix F). Concurrently, total carbon dioxide emissions grew at the same annual growth rate.[24]

Although the specific emission standards for thermal power plants had been listed in 1996, the provincial government did not issue any explicit regulation on the electricity industry. Earlier on, in February 1995, the People's Bank of China (PBoC) issued the Notice on Implementing Credit Policies and Strengthening Environmental Protection Work, which could be regarded as the bud of China' green finance, requiring financial departments at all levels to control the construction of polluting projects through loan review and encourage the development of industries that are conducive to environmental protection. Later this year, the local bank, for the first time, issued the document on linking credit risks to environmental pollution, constraining granting loans to the heavy pollutant companies (Interviewee B2, December 2018; Xie, 1996). However, coal-fired power firms were excluded from the list of concerns because of the lack of plants' emission data and assessment criteria (Interviewee B, October 2018). Interviewees from the government and the bank all blamed the lack of environment-monitoring equipment for the fact that they were blind to polluting air emissions from the coal-fired power industry (Interviewee Bp1, Bp2, B1, Gp1, 2018; B2, G1, G3, 2019. Indeed, at that time, there was no environmental impact assessment (EIA) agencies available and was a shortage of emission monitoring equipment and know-how.

From the mid-1990s to the early 2000s, the local media compensated for the lack of institutional and technical environmental supervision. With the emergence of investigative journalism in China in the mid-1990s, a local investigative newspaper was launched. Accompanying the central government's encouragement for journalists to reveal environmental damages from human activities, environmental problems became hot topics for Chinese journalism (Tong, 2015). As one of the national investigative journalism pioneers, the local newspaper frequently reported on pollutant projects across the province, yet

[24] Self-calculated based on the data issued by Y. Shan et al. (2018).

with limited coverage of coal or coal-fired power sector. Interviewee Gp2,[25] who once worked in the local investigative newspaper, indicated that:

> The reason why the media was silent on the pollutant coal-fired power sector was complicated but also straightforward. It was easy for journalists to expose obvious water and land pollution caused by a papermaking firm rather than reporting on air pollution without any solid evidence and not easily traced by thermal power plants; on the other hand, in the ideology of local residents, from whom the journalist sourced parts of their evidence, the power generation industry is to too closely related to their lives, and they considered the pollution from power generation to be acceptable. (Interviewee Gp2, January 2019)

On the discursive level, the public treated the pollution from the power plants for granted as they believed that ‘coal is the vital essence of better life’ (Interviewee res2, January 2019). For politicians, generating electricity from coal enabled the heavy industries to prosper, which kept the provincial GDP growing and benefited their career promotion. Thus, from the mid-1990s to the early 2010s, developing coal-fired power plants was deeply rooted in political ideology. For generators, burning coal could ensure the reliability of the power supply, which was, is and will always be their fundamental principle (Interviewee Csp1, Csp2, Cs1, Cs3, 2018; Cs4, Cs6, R, 2019). Taken together, powering daily life and economic growth with coal was 'common sense'.

Regarding the renewable power generating sector, although the Renewable Energy Law was promulgated in 2005, the local electric SOEs had no interest in developing renewable energy power plants, mainly due to weak material forces. First, financial incentives for constructing renewable energy power plants were not as attractive as those for thermal power plants. Generators could receive financial incentives from both banks and the government, including preferential loans and subsidised tariffs for developing new thermal power plants or upgrading the existing coal-fired fleet with emission reduction systems, such as flue gas desulphurisation (FGD), electrostatic precipitators (ESPs) and selective catalytic reduction (SCR) (Interviewee Csp6 & Cs7, January 2019), as well as developing the combined heat and power generation units (CHPs). Second, the

[25] Interviewee Gp2 was a journalist on environmental issues in the local investigative newspaper. However, as the practice of investigative journalism declined from the early 2000s due to political crackdowns (see also Tong (2013)), he resigned to work in the government.

cost of renewable energy technology, such as wind turbines and solar panels, is not competitive.

Moreover, on the organisational level, there was no department in the provincial and municipal government to guide or regulate the renewable energy market. The development of renewable energy projects depended on the SOE's will (Interviewee Gp1, 2018; Gp2, G1, G3, 2019). In fact, the local authorities had to rely on the SOEs to execute the instructions and regulatory decisions from the central government because SOEs and government sectors operate within a single administrative hierarchy, within which corporate executives often outrank regulatory officials (Wu, 2019).

Nevertheless, an SOE built the first wind farm in C-province in 2008 in city1, which has the geographical advantage for developing mountainous wind power projects, to meet the high demand for electricity because of the city's prospering metallurgy and electrolytic aluminium industries. However, in the following five years, the wind power farms did not expand widely in C-province and were exclusively located in city1 and run by two SOEs. The managers from the SOEs indicated that they took on the wind because the central government mandated it and never saw it as a business opportunity (Interviewee C1, December 2018).

Thus far, from 1997 to 2012, the coal-fired power sector enjoyed hegemonic stability through the alignment of political, discursive and economic elements, that is, solid government-business collusion, undoubting public support, and favouring material forces of production. Such coal-fired power historical bloc was strong and not actually threatened by low-carbon initiatives; instead, it adapted and absorbed challenges through lending support to promoting clean coal technology and investing in renewables in parallel to far more additional investments in coal.

4.4.2 Contesting coal-fired power hegemony (2013-2015)

The coal-fired power sector trembled for the first time, in 2013, in the outbreak of nationwide smog and under the new leadership of the CCP. With the rapid development of the Internet and social media, Chinese people were able to collect information through multiple channels. They learned of particulate matter with a 2.5-micrometre diameter (PM 2.5) from the U.S. embassy in Beijing in 2012 and its adverse effects on personal health. They also learned that PM 2.5 mainly comes from burning fossil fuels and found that the air quality indicators issued by the Embassy and the local government were seriously inconsistent (Kelly & Jacobs, 2014). When the nationwide smog broke out in 2013, Chinese netzines were outraged at the pollution level and data quality. To maintain the CCP's authority, the new leadership of the CCP pledged to build a Beautiful China and give high priority to protecting the environment at its 18th National Congress. China's Environmental Protection Law was amended for the first time since 1989. The new law was effective in 2015 with the amendments introducing a framework for facilitating public participation, a stricter exemplary system for polluting firms and indicating local government officials who do not take punitive measures against polluters would face criminal liability. This is closely followed by the national energy plan (StateCouncil, 2014a) and the electricity reform (StateCouncil, 2015a) with a priority to promote the efficient operation of thermal plants and increase the utilisation of renewables (NDRC & NEA, 2015a, 2016b; NDRC et al., 2014a). Also, at the international level, President Xi Jinping announced that China would reach its peak of carbon dioxide emissions no later than 2030, offered an absolute emission-reduction target and ratified the Paris Agreement. Such moves symbolically and practically indicated the Chinese government's ambition to play a global leadership role on climate issues (Christoff, 2016; Wong & Karplus, 2017).

Nevertheless, putting ambitions into results required actions at the local levels. A television documentary about China's overwhelming air pollution crisis, *Under the Dome*, released in early 2015, brought the focal on the locals. It reflected the local government's weak enforcement of environmental regulations and exposed the resistance and corruption in powerful fossil fuel industries when dealing with environmental issues. Meanwhile, Xi launched a rigorous anti-corruption campaign nationwide, of which the fight against the vested interest groups in the thermal power industry is one of the main targets (Isoaho et al., 2017). The central government set up the Central Environmental Protection Supervision Team to frequently inspect local environmental governance, and the local coal-fired power plants were their primary targets. Given that violators would face severe punishment, the local regulators announced mandatory requirements for all coal-fired power plants to instal real-time monitoring systems for waste disposals and required the generators to instal desulphurisation and denitrification techniques; thus, the generators sped up retrofitting (Interviewee Csp1, Cs1, & Cs2, 2018; Cs4 & Cs6, 2019).

For coal-fired power generators, which are mainly SOEs in C-province, the cost of environmental protection has always been high; for example, the coal-fired power plant located in city1 and city2 spent about CNY200 million on installing FGD & SCR equipment and around CNY20 million on enclosing the coal yard in 2016. However, such cost would not have a considerable impact on the corporate profitability from 2011 to 2015 because the coal price in the same period was very low (Interviewee Cs1 & Cs3, December 2018). As for renewable energy, SOEs still did not interest in it. The informants from the SOEs explained three reasons. First, before 2015, power projects with a total capacity above 50 megawatts would be required central oversight; SOEs, which prefer to invest in large scale energy projects, would rather expand their conventional coal-fired power generation business because their performance was mainly evaluated based on total capacity instead of profits. It also explains the constant increase in new coal generation projects despite the decreasing utilisation hours of coal electricity since 2013. Second, although wind power plants are exempt from corporate income tax for the first three years and levied by half in the next three years, the initial investment is significant, usually not profitable in the first few years, and companies actually could not enjoy tax benefits. Last and most importantly, the overwhelmingly competitive coal price. Although the weighted-average levelised cost of electricity (LCOE)[26] of utility-scale solar PV and the onshore wind had dropped since 2010 (see Figure 4-3), generating electricity from burning coals was still much cheaper than that from solar PV and wind. SOEs' coal-fired power business still could get positive profits regardless of under-utilisation and the massive expenditure on retrofitting. Thus, the SOEs,

[26] Levelised cost of electricity/energy (LCOE) is the cost per unit of energy from an energy generating asset that is based on the present value of its total construction and lifetime operating costs, divided by the total energy output expected from that asset over its lifetime (REN21, 2020).

who run most coal-fired power generation businesses in C-province, stuck to their relentless pursuit of building advanced coal-fired power plants.

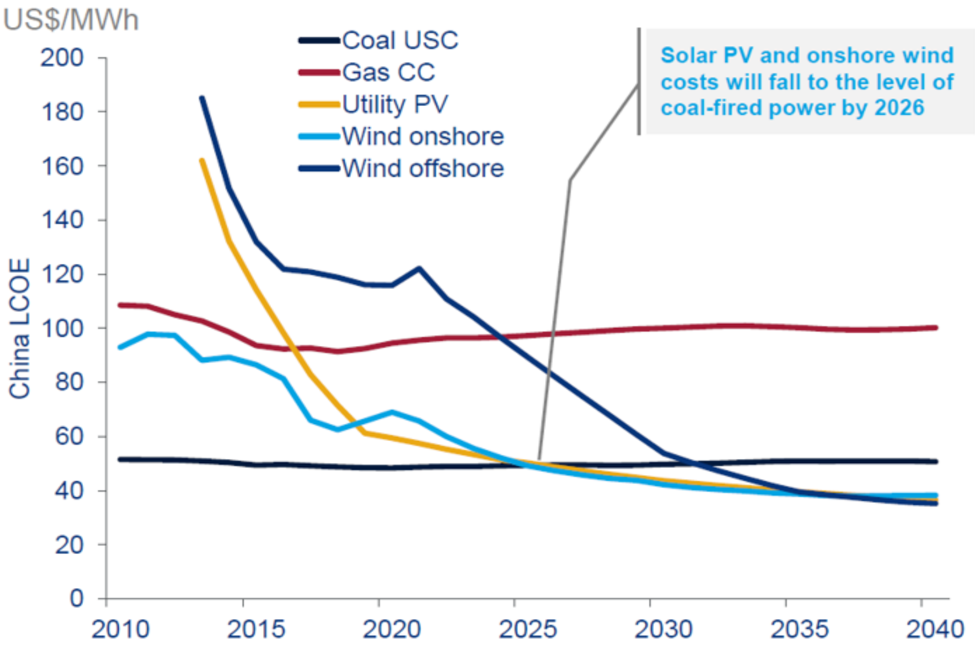

Figure 4-3 Average power generation cost (LCOE) trend in China

Source: Wood Mackenzie (2019), China Provincial Renewables Competitiveness Report Brochure

However, the local government changed its attitude towards renewables to support the local renewable deployment strongly. The environmental governance pressure from the central government was one reason, and more importantly, to save the local solar module manufacturers. Such change was particularly pronounced in city3, which used to be one of China's largest solar-module manufacturing bases. Before 2009, China's solar PV industry was mainly export-oriented, with 95 per cent of solar panels exported to overseas markets (Lester & Thomas, 2018); after 2009, due to the world financial crisis and the anti-dumping and anti-subsidy lawsuits pushed by the United States and the European Union against China's solar module manufacturers, the overseas market slumped. The period from 2010 to 2012 witnessed a wave of bankruptcy of the solar module manufacturers (P. Wang, Liu, & Wu, 2018). Shutting down the local manufacturing facilities placed pressure on the local government because of the fear of provoking social unrest and economic loss. To ease the severely adverse impacts of the embargos, the municipal government supported the local manufacturers to build the province's first utility-scale solar PV power farm. Key supports were providing land, tax reductions, helping to obtain building permits, and supporting the manufacturer's applications for funding from the provincial government and Beijing (Interviewee G3, January 2019). As the municipal authority in city3 put it:

> We had to devote ourselves to promoting the solar PV generation business to save the local manufacturing business. We supported the local manufacturers to build solar power farms and helped them get loans from the bank. However, it took me almost two years to get the provincial NDRC's approval, and the Ministry of Finance ultimately did not assign us any funding. It was challenging but worthy of it. We saved the local business from bankruptcy and attracted SOEs to purchase the private-owned solar power farms and invest in utility-scale solar PV projects, making us a pioneer in the region. (Interviewee G3, January 2019)

The success of the province's first utility-scale solar PV project further strengthened the tight links between the local solar PV manufacturers and the municipal government. Given local job stabilisation and the potential taxation gain, the municipal government was highly motivated to develop solar farms further. It includes solar PV project development in its annual government working papers starting in 2013 and is associated with the local manufacturers lobbying the provincial government and central government for additional beneficial policies. The municipal government also invited provincial leaders and authorities from Beijing for site visits and built demonstration utility-scale solar PV farms. Meanwhile, the local leading solar PV manufacturers, exclusively private-owned firms, established an industry association and collaborated with municipal government and experts, bypassing the provincial government to lobby the central government for better feed-in-tariff and local industry rearrangement (Interviewee G3, G4, & Cp5, 2019). The industry association actively expanded its influence at the national level and exerted a far-reaching impact on establishing China Photovoltaic Industry Association (CPIA) in 2014 (Interviewee G3, Cp5, & Cp6, 2019). The local association leader became one of the CPIA board of directors.

The collaboration between local government and private green firms changed city3's electricity market. Yet it had limited voice to coordinate with banks and the provincial government. Interviewees from the provincial government emphasised their concerns of reliable electricity supplies, as one informant commented, ‘ensuring reliable electricity supply has always been the government’s ultimate priority’ (Interviewee Gp1, December 2018). During the 12th Five-Year-Plan, C-province strived to transition from high energy-consuming industries to high-tech and service industries. The rapid growth of the tertiary sector and residential electricity with peak-valley characteristics leading the growth rate of peak load is higher than that of total electricity consumption. The peak-to-valley ratio increased from 30.6 per cent in 2010 to 38.8 per cent in 2016.[27] Both the interviewees from the provincial government and the State Grid remarked that ‘we do not lack electricity; what we lack is power peaking capacity’ (Interviewee Gp1 & R, 2018). Given that the electricity storage technology is underdeveloped, intermittent wind and solar power could not ensure the flexible and stable operation of the power system. Under such circumstances, it is not easy to reduce coal from the electricity grid. Meanwhile, the commercial banks tightened their lending policies to the renewable energy industry, especially to the solar PV industry, mainly because of the extensive bad debt from lending loans to the solar PV manufacturing firms in previous years. It was clearly stated in the local bank’s annual financing guidance on the power generation industry (2013 to 2015) that all loans to the entire supply chain of the solar PV sector were strictly banned, and loans to the solar farm projects were not encouraged. In practice, the local banks disapproved of all the renewable power generation projects between 2013 and 2015 (Interviewee Bp1, 2018; B1, B2 & B3, 2019).

Taken together, the hegemonic position of the coal-fired power bloc became shaky starting in 2013. Contestations over the ‘coal forever’ common sense had been arising. On the discursive level, the public realised the hazard emissions from burning coals threaten their health. The local authorities recognised that developing renewable energy power projects could benefit the local development. Some began to favour the green energy projects expecting the spillover effects such projects would have on other industries and, ultimately, their careers. On the organisational level, the nationwide anti-corruption campaign and the proliferating environmental governance dealt an overwhelming blow to the coal-related industries, creating a good timing for the

[27] Data sourced from the C-province Energy Economy and Power Development Research Report published by the regional State Grid in 2016.

rise of the renewable energy industries. The local green entrepreneurs collaborated with the municipal government to expand the domestic renewable energy generation market. On the material level, the advanced emission monitoring and social media technology lifted the emission control pressure of the power plants and local government. To prop up the local solar PV producers, the local government and corporate managers were forced to develop the solar PV power farms locally. Also, from 2013, the central government started to launch a series of measures, such as the ambitious feed-in-tariff system and renewable energy quota system, to promote the development of renewable energy power farms. Overall, the coal-fired power bloc was contested and exposed to various challenges. However, the absence of SOEs and financial support from the banks and the weak support from the provincial government moderated the effects.

4.4.3 Re-organising hegemony (2015 to present)

Wind and solar PV power have been experiencing rapid growth in C-province since 2015. Meanwhile, various types of renewable energy projects have been proposed and initiated, such as the waste-to-energy and biomass power projects. However, they were still at the project appraisal stage when this research proceeded; thus, no operation data was available. Figure 4-4 shows the trend of regional wind and solar PV power, respectively. C-province added 700 MW of wind power in 2015, which increased the total installed capacity by 73 per cent compared to 2014. Solar power increased by 2,430 MW in 2016, a nearly six-fold increase from 2015. In the following years, generation from wind and solar continued to rise at a double-digit rate per year. The accelerated uptake of wind and solar PV was attributed to the integration of economic strategy, discursive structure, and organisational capacity.

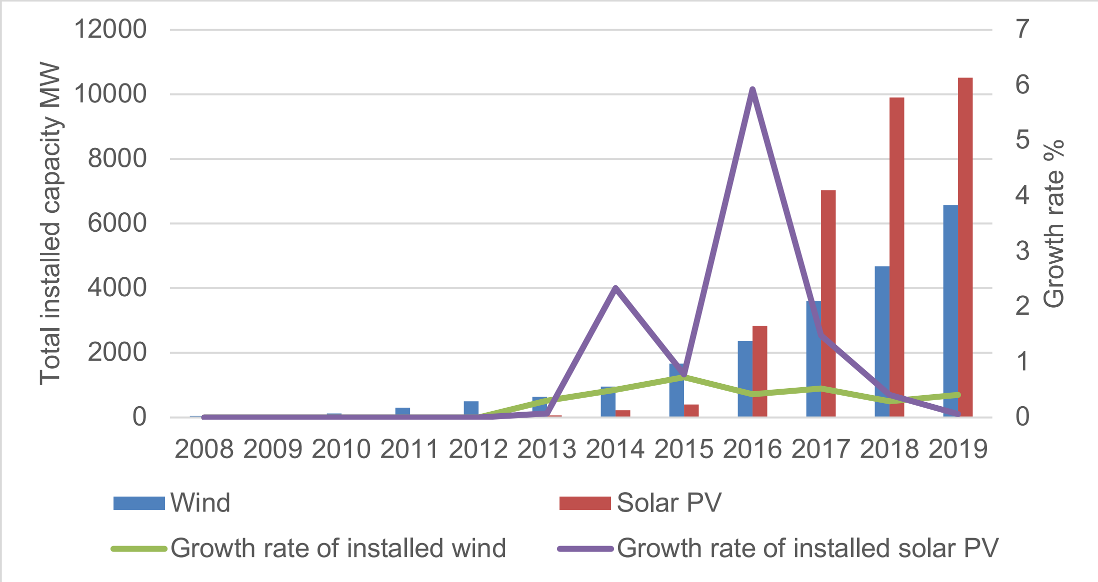

Figure 4-4 Total installed capacity and growth rate of wind and solar PV in C-province
Source: C-province's energy regulatory office of the National Energy Administration of China

On the material level, continued cost reductions of deploying wind and solar PV while soaring coal prices led to wind and solar PV approaching cost parity with coal-fired generation (as shown in Figure 4-3). Coal prices soared in 2016 (see Appendix G). All thermal power plants suffered severe losses in 2016 and 2017, and it is expected that overcapacity, under-utilisation, and a low load factor of the advanced coal-fired power plants would be new normality (Interviewee Csp1, Csp2, Csp3 & Csp4, 2018; Cs1, Cs2, & Cs3, 2019). On the other hand, the existing renewable power farms showed good profitability because of their resilience to coal prices, lower costs for wind turbines and solar panels, and higher subsidies than coal-powered electricity. SOEs started to recognise developing renewable energy projects as business opportunities rather than political intentions alone. This is further strengthened by a new round of SOE reform in 2016, highlighting that profits should take precedence over mere size (Xiliang Zhang, Li, & Li, 2016). SOEs shifted their primary goal from only capacity expansion and accumulation to profits. Meanwhile, to address the high curtailment rate of solar and wind power in northern China, the central government strengthened restrictions on renewable energy deployment in regions with high curtailment rates in 2016. SOEs shift their investment focus to major demand centres - some of the most populous provinces in the central and eastern regions. Thus, since 2016, with the strong support from the headquarters of the power conglomerates, SOEs in C-province have actively invested in lucrative renewable power generation projects.

The continued growth of wind power in C-province also greatly benefited from the low-speed wind turbine technology development, which was matured and widely commercialised after 2015 (Interviewee Cp1, January 2019). Most wind power projects built after 2016 are low-speed wind farms located in plain areas. The first low-speed wind farm in C-province was invested and run by a private firm in 2015. The firm is also a wind turbine manufacturer and sought to test its new models of low-speed wind turbines. Compared with the SOEs, private firms are at a disadvantage in dealing with the government; however, they have more diversified financing tools, are more flexible in handling project approval procedures, and have more flexible exit mechanisms (Interviewee Gp1 & G2, December 2018). Private firms adopt a desirable performance appraisal mechanism, providing desirable incentives for their employees to get the project permits and extensively hiring young graduates with renewables degrees (Interviewee Cp1 & Cp2, 2018; Cp3, Cp4 & Cp5, 2019). To a certain extent, they are more specialised in renewable energy projects than SOEs, where the managers in charge of wind farms previously worked in thermal power plants, and so were the majority of employees (Interviewee Csp4, Csp5, Cs3, Cs 9, & Cp1, 2018).

The dramatic growth of the installed solar PV capacity mainly depends on government policies, particularly the Solar PV for Poverty Alleviation Programme. It was launched in early 2016 jointly by the government offices and policy banks to promote distributed solar power generation in each household in listed poverty areas (NDRC & NEA, 2016c). The most significant advantage of this policy is that it enables solar PV projects to get loans from banks (Interviewee Bp2, B2, Csp2, Csp3, Gp1, & G3, 2018). Although the average solar PV module price fell from around CNY40,000/kilowatt in 2010 to CNY8,464/kilowatt in 2015, SOEs were reluctant to develop solar power projects because of the financing difficulties.

Although the financial institutions have promoted green finance since 2009 and have issued several green bonds and green securities, those who enjoy these preferential policies are group-level projects (Interviewee Bp, B2, & Csp5, 2018). When it comes to local corporations whose renewable energy projects could not reach a large scale because of geographical restrictions, they could not benefit much from the green finance policies (ibid). Especially solar PV projects which require ample land space, and for C-province with high population density and shortage of land resources, it is not realistic to build large-scale solar energy projects. On the other hand, the nature of commercial loans cannot match small-scaled distributed solar energy projects. Many distributed solar projects developed in the early years were financed through personal loans; however, nowadays, personal loans are tightened and no longer granted to energy projects (Interviewee Bp2 & B2, 2018). When PBoC, the ministries and commissions of financial systems, together with NDRC and the Office of Poverty Alleviation and Development, jointly released the policy of ensuring financial support for poverty alleviation (PBOC, 2016b) in 2016, Solar PV Poverty for Alleviation projects got vigorously promoted. Solar panels are widely installed on housing roofs and agricultural greenhouses in poverty areas. Villagers could consume the electricity generated from the solar panel and sell excess electricity to the grid firm. The local grid is obliged to purchase such electricity. Since the local government, commercial banks and SOEs all have the task of achieving poverty alleviation, the PV poverty alleviation farms are quickly approved, built, and on-grid. Therefore, the total installed capacity of solar PV surged after 2016.

Meanwhile, the central bank issued guidelines on building a green financial system, further suppressing polluting investment and encouraging investment in green projects (PBOC, 2016a). Given the severe overcapacity of the local coal electricity and comprehensive policies prioritising expanding renewable electricity, local banks have halted issuing loans to all coal-fired power projects except CHPs since 2015. However, they are still generally not supportive of solar PV projects considering the risks of the volatile economic return of the projects. One interviewee from banks commented that ‘although the cost of solar panels is expected to hit bottom around 2025, after deducting the subsidy, it would still be much higher than that of fossil-fuelled electricity, hence making the solar projects less economy; thus, most of the solar power farms would experience losses’ (Interviewee Bp1, August 2019). His opinion coincided with the result from a research report published by Wood Mackenzie, which indicated that 'across most of China's provinces and regions, there is still a renewable cost premium over coal power, averaging 26 per cent for wind and solar, down from 100 per cent in 2010…only Shanghai and Qinghai have cost-competitive renewables today.' (A. Huang, 2019). The local banks considered waste-to-energy plants the most promising ones among all the renewable energy generation projects because, being the most populous province in the country, C-province generates an immense amount of household and business rubbish. Burning waste for power is a solution for the region's sustained energy transition and could avoid the escalating 'Not-In-My-Backyard'[28] issue that other types of electricity generation projects have faced in recent years (Interviewee Bp1, Bp2, & B2, 2018).

Cost reductions and preferential loans constructed the reliable material foundation of the emerging renewable hegemony, albeit the weakness in renewable investment still exists, as shown above. Nevertheless, the changing economic structure and sustained policy support drive strong renewables growth. Wind and solar PV plants challenged existing coal-fired power plants. Meanwhile, public buy-in is also crucial to the rapid growth of renewables, just as Nyberg et al. (2013) underscored that 'hegemony entails forging common identities and interests among disparate groups through the articulation of discourse in civil society' (p. 437).

Programmes like the Solar PV for Poverty Alleviation encourage the citizens' involvement in the energy transition. By installing solar PV on their rooftop or farmyard, individuals, households, or communities become 'prosumers' - they not only consume electricity but also produce it (REN21, 2020). Such programmes promote community choice aggregation[29] and shared ownership[30] of renewables, contributing to the increased adoption of renewables. In less than two years after the launch of the programme, solar PV projects were established

[28] 'Not-In-My-Backyard' refers to the behaviour of individuals opposing a development project (such as a renewable energy plant) being built near to where they live because of perceived impacts and costs to themselves (REN21, 2020).

[29] Community choice aggregation allows the local governments to produce renewable energy on behalf of their residents while still receiving transmission and distribution services from existing utilities (REN21, 2020).

[30] Shared ownership refers to the collective ownership and management of renewable energy assets (REN21, 2020).

and operated in 18 townships governed by city3. Most of the townships are located in the mountains and suffered poverty because of the severe water shortage resulting in crops that could barely grow and, therefore, have massive wastelands. The township governments set up TVEs to invest in solar PV systems on the villages' wastelands. In the visited township, the township government established its TVE in 2016 and invested in 22 solar PV sets in its jurisdictional village. By the end of 2016, all the projects were on-grid. The revenue was prorated: 60 per cent was returned to the villagers, 30 per cent was the income of the villager's committees, and the TVE owned the remaining 10 per cent for the maintenance of the solar PV power stations (Interviewee Ct1, January 2019). The villager's committees then spent this revenue on other projects within the village, such as road maintenance and the re-education of the villagers. With the support of the municipal government, roads connecting to and within each town had been refurbished and installed streetlights equipped with solar panels. The villagers received training on the basic operation and routine maintenance of the solar PV power site and were then hired to work for the newly established power stations in the following years. Two villagers who participated in the interview worked in the local granite quarry and deep processing factory. The factory was shut down in 2016 because of not meet environmental standards. Being part of the programme, they could receive payment from electricity generation and extra income for cleaning the power site, such as cleaning the solar panels and removing weeds under the panels (Interviewee res1& res2, January 2019). They also got hired to construct the new solar power PV site. Besides, they mentioned a remarkable improvement in the local air quality in recent years. Nevertheless, the manager of the TVE expressed his concerns about the future of such projects, which are the shortage of professionals and difficulties to get further financing. The interviewee explained that 'there are no professional technical or management personnel to assist us in operating the power plants, resulting in the fact that the TVE does not achieve the expected financial returns, which, in turn, leads to financing difficulties for the subsequent projects. We expect the higher-level government to introduce policies soon to attract professionals to assist the work in poverty-stricken areas so that such projects could sustain' (Interviewee Ct1, January 2019).

A similar situation happened in the other visited TVE in the township under the jurisdiction of city2, which focused on the installation of rooftop solar PV systems and agricultural PV. This township is located on the plain; however, the soil is primarily sandy, which is not ideal for growing various crops and for the erection of wind turbines. In late 2015, the newly assigned governor of the township government contacted the manager of a private wind turbine manufacturer[31] to build an experimental base for the agricultural PV using the bifacial systems. It was proved to be a highly worthwhile project as it not only brought additional income for farmers from electricity production but also improved crop yields, reduced evaporation, provided shade for livestock and prevention of wind and soil erosion (Interviewee Ct2, res3, res4, & res 5, 2019; res3 & res4, 2020). The success of this experimentation attracted attention from the SOEs. One SOE purchased this project in 2017 and expanded agricultural PV to other areas.

Thus, the findings from these two cases of TVEs indicate that the local renewable energy transition has won the support of its population. As the data in Appendix F shows, in 2017, annual installations of residential systems (at 1,740 MW) increased 3.8 times relative to 2016. Moreover, the total installed capacity of distributed solar PV continued to double in 2017, reaching 3,910 MW. At the end of 2018, centralised solar PV power plants accounted for 60 per cent of annual grid-connected installations at the end of 2018, with distributed systems making up the remainder. Although the northern and western provinces are still home to the majority of China's wind and solar power capacity, according to the statistics from REN21's reports,[32] C-province has become one of the top provinces for official grid-connection additions since 2017.

[31] The interviewed governor mentioned that he and the firm's manager went to the same MBA school and attributed the success of such projects to the importance of informal connections *(guanxi)* between the business and government authorities. The informants from the municipal government (Interviewee G2 & G3, 2018) also stressed the importance of such informal coalitions in promoting renewable energy projects.

[32] See the annually released *Renewables Global Status Report* by REN21 from https://www.ren21.net/reports/global-status-report/

4.5 Discussion

The previous section has explored how different actors interact in the local energy transition. The findings have shown how the hegemonic position of the 'historical bloc' of the coal-fired power industry has changed, and the new renewable energy bloc emerged over the past two decades on three levels: the level of material forces of production, the discursive level, and the organisation level. This section first provides a comparative analysis of the transformative alliances, indicating what constitutes a coalition, how changes to alliance makeup lead to the transition and the key driving forces; and then suggests implications of these results. Figure 4-5 displays what the alliance of the local electricity industry was like in each stage and tracks what has changed over time. The green arrows present the main driving forces of the change. The corresponding positions of different actors on the vertical axis roughly represent the level of each actor's adoption of renewable energy projects. The area of the overlapping parts of the circles in the figure describes the degree of cooperation between the actors.

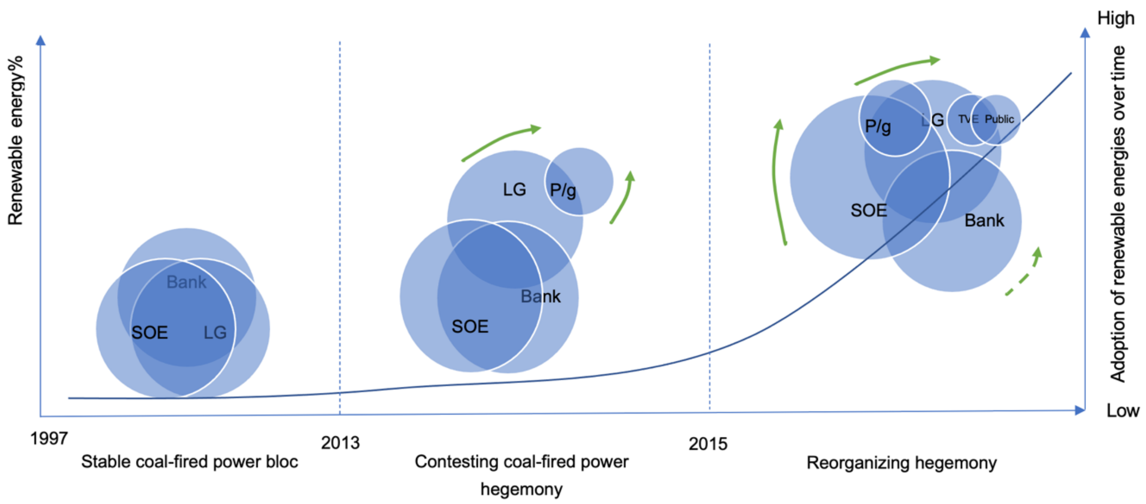

Figure 4-5 The transformative alliances in the local energy transition

4.5.1 Almighty coal

From 1997 to 2013, there were three main players in the local electricity industry: state-owned electric generators, local government, and state-owned commercial banks. Recognising that generating electricity from burning coal was of central importance to continued economic growth, they built an alliance that was structurally powerful, which can be termed a coal-fired power historical bloc. Unlike emission reduction goals or economic growth targets written into the local cadre's annual evaluation, the renewable energy development target was optional, enabling both provincial government and city government to have a choice of deploying renewables or not. Considering the large share that the coal-based industry contributed to the local economy, the provincial government was highly motivated to develop it further. Electricity magnates also could choose to and be capable of expanding the deployment of renewable energy. However, driven by the ambition of massive capacity accumulation and convenience of existing infrastructure, they would rather advance the current energy system in line with the national efficiency strategy than turn to the new energy system. Local utility projects still heavily depended on bank loans. Given the long-lasting and deep-rooted relationship between SOEs and local commercial banks, the banks always prefer to finance any types of utility projects held by SOEs. The energy efficiency strategy towards sustainability did not reduce total emissions, but instead consolidated the coal-fired power bloc. This finding broadly supports the Jevons paradox that higher efficiencies of energy conversion do not necessarily result in actual energy savings but accelerate the consumption of coal anew, and the efficiency gains do not negate environmental impact (Alcott, 2005; Jevons, 1865; Smil, 2018). While the mass public was simply energy users at this stage, they were not active actors. They viewed receiving reliable electricity from coal-fired power plants as the guarantee for a better life and took emissions from burning coal for granted, in other words, the 'natural way of doing thing' (Cox, 2007, p. 541). Such 'passivity of the great popular masses' relates to Gramsci's common-sense conception (Gramsci, 1999, p. 414). At this stage, the coal-fired power sector was accepted as what Gramsci calls 'common sense' – an ideological conception of the world that is taken for granted in creating the future (Gramsci, 1999, pp. 430, 625, 630) and therefore established hegemony by winning over agents and groups to its dominant position. Before 2013, the coal-fired power historical bloc was formed stably and effectively, leaving limited space for renewables.

4.5.2 Contested alliance of local government and entrepreneurs and creative manoeuvres by local governments

Nevertheless, hegemony is ‘contingent’ and ‘unstable’ (David L. Levy & Egan, 2003, p. 807), and as Gramsci stressed that the ‘relation of forces in continuous motions’ points to the possibilities of the ‘shift in equilibrium’ (Peter Newell, 2019, p. 42). Since 2013, the coal-fired power historical bloc got disturbed as the local government drifted away from it to build an alliance with local solar PV manufacturers. It is worth noting that the primary motivation for forming the new coalition for the local government is the same as that behind the construction of the hegemonic coal-fired power alliance, which is the economic growth-based evaluation of local officials’ performance. When the export recession hit the local solar PV companies, the local government, driven by the desire for economic growth, became the spokesperson for PV firms’ interests holding out its hands to assist them through bankruptcy and reorganisation, seeking the local market for deploying solar PV, inject capital, coordinate with financing and mergers, and so on. Their alliance is informal, building on the personal relationship between government officials and manufacturers. This finding was also reported by Dai (2015) and Harrison and Kostka (2014) in their studies on the implementation of climate-relevant policies in China. The coalition was proved to be productive with the success of agricultural PV projects. Such an alliance could exist and succeed is also because of their very cautious strategy of avoiding direct confrontation with the incumbents and seeking alternative market space, for instance, developing distributed solar power projects that SOEs did not previously favour. This finding is consistent with that of Shen and Xie (2018), who found ‘peaceful rise’ of renewables in the national energy system – ‘China’s renewable energy development faced little resistance and harassment from the so-called electricity incumbent’ (pp. 413-414).

The entrepreneurial activities of local government could also be seen in the case of promoting local low-speed wind power projects and establishing TVEs to promote distributed power generations. These findings corroborate the findings of a great deal of the previous work in ‘entrepreneurial state’ by Duckett (1998), which depicts the local governments, notably at the municipal and district levels, possess a development- and interest-oriented nature and were ‘not really bureaucratic at all, but business-oriented and profit-seeking' (Duckett, 1998, p. 167). The local governments embark on profit-seeking and risk-taking endeavours to promote local development as a whole and seek economic profits for their own bureaux simultaneously. The entrepreneurialism of the local state allowed renewable energies to enter the region's electricity market. It is also clear from the case material that the interests of local authorities and private firms were aligned, and the external shocks provided a window of opportunity to try out the deployment of renewable energies. The local government-private coalition became an important mechanism in promoting the growth of the local economy and renewable energy deployment.

It is important to stress that the local governments were not jumping out of the coal-fired power alliance with SOEs and banks. They still need and have to rely heavily on SOEs to maintain reliable electricity generation. However, the role of local government was changing as the central state's determination and ambitions of the energy revolution got stronger. The local authorities have first-hand information, can implement the central state's plans according to local conditions, and effectively coordinate different counterparties. They served like what Gramsci posited of the 'Modern Prince', who could 'reveal weakness and points of leverage and possess the organisational capacity to intervene during critical windows of opportunity' (David L. Levy & Newell, 2002, p. 87).

The role of local government continued to evolve in the third stage. It can be seen in cases of TVEs and the agricultural solar PV project that the local government is not only a 'legislator' that 'modifies the mass habits, their will, their convictions to conform with the objectives which are proposed to achieve' (Gramsci, 1999, pp. 538-539), but also an 'educator' to 'create a new type or level of civilisation' (Gramsci, 1999, p. 508). The local state is not simply a coercive instrument to implement and fulfil the target set by the higher-level government. Still, it plays a broader role in reproducing social relations by forming the mass public's consciousness of green growth, starting with educating its residents on their capability to be active actors instead of receivers in the energy transition process. In this case, the local government is an interventionist state in both economic and cultural fields. Both the coercive side of the political power and consent from the mass public are critical for the rapid expansion of renewable energies and the formation of the renewable energy hegemony. This finding support Gramsci's argument that hegemony comprises both coercion and consent, and 'force is a component of hegemony that it predominates over consent, albeit not excessively' (Budd, 2013, p. 103). The interpenetration and interdependence of state and civil society become more evident, as shown in Figure 4-5, after 2015. This finding seems consistent with Gramsci's formula for the 'integral state' that 'State = political society + civil society' (Gramsci, 1999, p. 532). The local state's efforts to develop renewables in the rural areas, albeit fundamentally for their own interests, rewarded the subordinate groups with economic benefits. By further propagating the green growth ideas in the local community, the renewable energy projects received consent from the residents.

So far, I have discussed the changing role of local governments and their creative manoeuvre in bringing renewables into the local energy system. However, the renewable energy sector was far from forming a historical bloc without getting all the key actors, such as SOEs and financiers, on board.

4.5.3 The convergence towards the renewable energy historical bloc

It can be seen from Figure 4-5 that more actors are involved in the alliance to support renewable energy deployment. The local government-private business alliance still exists and continues to stimulate the development of renewable energy projects. Meanwhile, as discussed above, the mass public genuinely joined the alliance through their actions: becoming the prosumers and vigorous public criticism and oversight over the local government and business. More importantly, the alliance is getting support from SOEs, whose involvement has brought fundamental change to the speed of local energy transition. I will come back to this point later. The coal-fired power historical bloc is dismantling, and the renewable energy bloc is getting stronger; however, it is still not yet a historical bloc because of the weak involvement of the banks. As the comments from the local commercial banks indicate, the existing financial products could not accommodate the peculiarities of the renewable energy products and their diffusion, and of particular concern is the limited and volatile economic return for the distributed facilities; thus, they are reluctant to take the risky investments.

What is important for us to recognise here is that the motives for (in)action of the actors’ involvement in renewable energy projects are the same: seeking profits. As for the local government, their primary tasks are promoting local economic development, fostering jobs, and increasing tax revenue. The mass public is pursuing a ‘better life’, which de facto equals ‘better material life’, aiming to get a higher income, particularly for residents in rural regions, while climate change mitigation at best a ‘co-benefit’ (Schmitz, 2015). Corporations seek to generate profits to maintain and expand their business. Turning now to the electricity generators, SOEs keep dominating the electricity sector and the rapid scale-up of renewable energy deployment since 2015 is still essentially contributed by SOEs.

4.5.3.1 Big business: the game changer

The most obvious finding to emerge from the analysis is that big corporations, SOEs in particular, are the real game-changer. When their renewable-generation assets generate more profits than the coal-fired power-generation assets, they start to expand their renewable-energy portfolio (see Chapter 4). Their active investment in renewable energy power plants leads to a spectacular growth of the local wind and solar PV power generation capacity from 2015. Their participation has accelerated the region’s energy transition. However, it is important to acknowledge that the local SOEs were laggards in the previous stages of the local energy transition. Their reluctance to expand their portfolio into renewables had slowed down the transition process. Moreover, although they have prioritised the growth of renewable energy capacity since 2015, they continued to simultaneously increase their coal-fired power asset base, at least by 2019, albeit at a much slower rate. These results agree with the findings of Alova (2020)’s recent analysis of electric utilities’ adoption of renewables, in which she conducted a quantitative study of 3,311 utilities worldwide from fossil-fuelled capacity to renewables between 2001 and 2018 and pointed to power utilities lagging behind and even hindering the global transition to renewable energies.

Nevertheless, the evidence does show that local SOEs have started to engage in activities that support the energy transition towards renewables. They purchased existing privately-owned solar PV or low-speed wind power plants and then expanded their scale; or cooperated with established TVEs to upgrade and upscale the Solar PV for Poverty Alleviation projects. They also actively cooperated with the municipal government to seek renewable energy power generation projects that meet the national poverty alleviation standards. The effects are significant. Their change stems from a paradigm shift compared to the previous decades when the primary policy goal was only capacity expansion. As the massive ‘mad rush’ for capacity accumulation is no longer possible, the new paradigm consequently focuses on a differentiation approach to emphasise the role of renewables in their portfolio of power generation assets. They seek market space that was not favoured before for further development, for instance, distributed energy sources.

Thus, SOEs are both the delaying and propeller forces in the local energy transition. They are not only part of the problem but also a part of the solution. This is reminiscent of the case of the phaseout of chlorofluorocarbons (CFC), where the leading chemical firms played a vital role in the rapid elimination of CFC emissions. Because of their pivotal role in directing technological change, corporations were capable of influencing the governmental negotiations, and governments listened to business advice and actively sought to engage corporate actors in the international political process (Falkner, 2005). The corporate sectors shaped the evolution of the ozone regime.

At last, let us turn to the big state-owned commercial banks. The findings show the weak involvement of the local commercial banks in the transition process. They have stopped financing coal-fired power projects, excluding CHPs, since 2015; however, they are absent in promoting renewable energies. All the renewable energy generation projects are financed by a policy bank (China Policy Bank), SOEs and private capital. A recent report on China’s climate finance (CPI, 2021) revealed similar results that the state-owned commercial banks did not directly invest in wind and solar power projects (see Appendix H). The report adds that these banks are ‘the largest financiers of the central SOEs’ and therefore ‘partly responsible for the investment flowing from the wind and solar sectors through the central SOEs’ (CPI, 2021, p. 18). Despite that, commercial banks have tremendous potential to support the energy transition and accelerate the process. Perez (2002) argued the disruptive power of financial capital in technological revolutions. Peter Newell (2019) highlighted that 'financial capital has the potential to bring about disruptive change, just as it has done many times when the incumbent regimes fail to serve its needs' (p. 35). In practice, the overall green finance in China need to scale up by at least four times its current level – an annual average of CNY2.1 trillion in 2017 and 2018 (CPI, 2021) – to meet estimated investment needs – CNY9.545 trillion over 2021 to 2030 (CCICED, 2015). Thus, adequate finance will be the gear turning the rapid transition forward.

4.5.4 Implications

The findings have theoretical implications for the neo-Gramscian perspective. The neo-Gramscian concept of historical bloc refers to the complex interrelationships between economic, social, and political structures that shape the dominant ideology and power relations. The historical bloc is that it is not static but rather subject to change through the struggle between dominant and subordinate groups. In the context of the energy transition, neo-Gramscians argue that the dominant fossil fuel regime is not easily displaced and that the transition to a sustainable energy system requires a fundamental shift in the balance of power. In addition, the dominance of fossil fuel interests and the power structures they control make it difficult to shift towards renewable energy sources. This dominance is reinforced by cultural and political narratives perpetuating the idea that fossil fuels are necessary for economic growth and prosperity. However, findings from this research shed light on an alternative path to the energy transition that does not necessarily require a fundamental shift in power relations. From the case study of the local energy transition, we can see the existing power structures were able to adapt and incorporate new technologies and energy sources. Instead of being replaced by the renewable energy actors as the rival group, the fossil fuel historical bloc is transforming itself. The shift towards renewable energy sources is happening despite the dominance of fossil fuel interests.

These results have important implications for sustainable transition studies. They draw attention to the importance of considering the power relations and their impacts on the direction and momentum of the transition. Specifically, the findings of this study provide insights into conditions and possible strategies for a rapid green transition. The results suggest the convergence of material forces of production, coercive forces of the state, and supportive discourses that together form the hegemonic position of the renewable energy alliance. This closely ties to Gramsci's understanding of hegemony and indicates that fostering alliances in favour of green transition requires 'a unison of economic and political aims' by coercion and 'intellectual and moral unity' through consent (Gramsci, 1999, p. 406). The findings indicate that coercion does not result from the centralised authoritarian regime but is attributed to the 'active politician' that Gramsci (1999) describes as 'a creator, an initiator' (p. 390). It would be misleading to explain the rapid uptake of renewables due to a big push from the authorities along a predetermined path. The local authorities carried out the strategy of 'pragmatic innovation' (H. Schmitz & Scoones, 2015, p. 27). To avoid confrontations with the incumbents, they promoted unconventional distributed renewable energy projects. In doing so, they conducted step-by-step experimentation. They created 'transitional institutions' (Qian, 2003), like TVEs, that adapted the local conditions to the broader context at each stage of the process, and through which they could align the interests of the decentralised actors – residents and private corporations – with those of the reformers in SOEs and central government. They exercised their power to make the residents become prosumers. When the citizenry received the de facto rewards from the renewable energy projects, they, in turn, reinforced the position of renewable energies in the local power system. Thus, reaching consent in civil society need concrete material basis. Instead of propagating environmentalism or climate change, the local state's pragmatic and diversified strategies seem effective and efficient, which brings the mass public into the transition process and further attracts the other major players to get on board. The pragmatic approach is also reflected in the interactively formal and informal mechanisms. Officials frequently reinforced formal incentives such as subsidies and guidelines through informal ways such as personal appeals, persuasion and promises.

These findings support the idea that creating the new common sense forms the basis of a historical bloc. How to build a new common sense in a developing region? The results suggest three steps. First, as stressed above, the full assimilation of renewable energies depends on a solid material basis. The key to making renewable energy truly omnipresent in the industry and society lies in its wealth-generating potential. As Perez (2002) argues, ‘it is when the critical technological breakthroughs articulate them into a powerful, interacting and coherent set of *profitable business avenue*, influencing the whole economy, that their joint impact can become truly all-pervasive’ (p. 13). Second, the dominant politico-economic group need to take renewables for granted in the first place. The extent to which renewable energy technologies gain the elite’s support is critical to attracting adequate public or private investment, thereby increasing their deployment. In a television talk show (CCTV2, 2021), Zhang Lei, the founder and Chief Executive Officer of Envision Group,[33] viewed the ongoing energy revolution as a ‘cognitive revolution’. He explains that we should first and foremost recognise renewable energies as advanced productivity. The intermittent nature of green energy should not be treated as a threat to the grid; rather a force to drive the digitalisation of the grid system and change our consumption habits, and a force to advance our education and infrastructure systems. Harari (2015), in his book *Sapiens*, notes that the ‘Cognitive Revolution’ helped Homo sapiens outpace their fellow humans and the key elements of the ‘Cognitive Revolution’ are Homo sapiens’ unique capacity to believe in things existing in the imagination and cooperation. In the same vein, a 'Cognitive Revolution' within the industry would speed up the energy system's green transition. Thus, business actors and local authorities had better make proactive adjustments to their portfolios, jump out of their comfort zone to pursue unconventional business, and seek collaborations across industries. Third, the deployment of renewables needs to get public support. The results indicate that considering the range of reactions related to the public response to renewables can help build support for these technologies and ultimately encourage broader inclusion and participation. As discussed above, material incentives and education together would be essential to bring the citizenry in the developing regions to participate in the process.

4.6 Conclusion

This chapter set out to explore how a rapid energy transition might happen, why it might happen, who delayed the process, and who could speed it up. By

[33] Envision Group is one of China’s leading wind turbine manufacturers. It has expanded its business to smart grid, batteries and hydrogen and has become a world-leading green-tech company.

adopting a neo-Gramscian approach, this chapter has examined the dynamic and contested process of energy transition from a case study of the local power industry in China. Focusing on three sites – the economic system, organisational capacity, and discursive structure – where hegemony was established, contested and reproduced, this study has identified three stages of the local energy transition and showed the changing power relations between local government agencies, SOEs, private enterprises, TVEs, the mass public and local commercial banks.

This study showed that the introduction of renewables was driven by the government's directives and, more importantly, the economic incentives of local officials; the further green leapfrogging was triggered by the market interests of SOEs. The findings confirmed that a stable and effective renewable energy regime requires the formation of a historical bloc in both senses of the term: first, an alliance among states (across a variety of levels), leading businesses, small entrepreneurs, the mass public, and financial sectors; second, an alignment of economic, organisational, and discursive forces that coordinate the interests of the members of the bloc. The findings also indicate that the successful diffusion of renewable energy technology depends on physical and technological conditions but also the complex social embeddedness of the new technology. The technological, economic, environmental, and political factors can affect the extent and pace of renewable energy deployment; also critical is how civil society perceives these technologies.

This study has also shown the changing roles of prominent actors. Business is the key to a successful transition: SOEs delay the transition process while their participation in the late-stage speeds up the transition; private firms and TVEs actively develop renewable energy projects. The local government agencies act as green entrepreneurs and then as an integral state using create strategies pulling the region's renewable energy deployment. After changing from consumers to prosumers, the mass public genuinely became a part of the local energy transition. The commercial banks keep holding back financing the renewables, though they have the potential to bring about disruptive change and could be the gear of rapid transition. Notably, their primary motivation to change or not to change is the same: seeking profits.

Although the empirical context of this study is limited to a province in China, the findings may well have a bearing on other regions or economies which seek to break the fossil-fuel historical bloc and foster the creation of coalitions in favour of green transition. Pragmatic innovation, step-by-step experimentation, and transitional institutions rather than best practice institutions could be the key to the transition. Significantly, the field investigations in rural villages may offer practical implications for other underdeveloped regions. The distributed PV systems and off-grid systems could provide a potential niche for developing countries, where connecting rural communities may be more feasible and economic variable with off-grid systems. Meanwhile, the transition had to be facilitated by deep educational and cognitive reforms. Public support and adequate investment are the prerequisites of a rapid transition. Switching generating power away from fossil fuels to renewables is only one part of the energy transition. Equally crucial is the development of the infrastructure needed to enable the switch. Energy storage, improved transmission and distribution networks, enhanced digitalisation to unlock load shaping are all part of the transition. Thus, accelerating the transformation of the power system is, in fact, accelerating a region’s progress in restructuring its economy towards a pattern of growth in advanced high-quality industrial sectors.

Chapter 5 Does It Pay to Become Green? Evidence from China's electricity generation industry, 2005-2017

5.1 Introduction

The growing awareness of the ill effects of air pollution and climate change stemming from the production of energy from fossil fuels has led to increased government regulation and ever-higher levels of investment by government and industry in alternative energy technologies and supplies. However, there is a continuing debate on whether a firm can benefit from undertaking environmentally friendly practices. Those who stress traditional economic trade-offs believe that complying with environmental regulation is costly and might hurt a firm's bottom line; opponents, on the other hand, treat green practices as an efficient and sustainable way to gain competitive advantages. The debate has been stimulated by Porter and van der Linde (1995), who contend that there is no trade-off and green business practices are almost invariably profitable. Numerous empirical studies have since been done to test the effects of corporate environmentalism on the bottom line, with mixed results (Albertini, 2013; Dixon-Fowler, Slater, Johnson, Ellstrand, & Romi, 2013; Endrikat, Guenther, & Hoppe, 2014; Orlitzky, Schmidt, & Rynes, 2003).

So far, existing studies of this issue have focused almost exclusively on investigating the effects of environmentally friendly behaviour on the performance of firms domiciled in developed economies, especially in the European Union and the United States. However, very little is known about the effects of corporate green practices on the performance of firms in developing countries such as China. Making this question more pertinent is the fact that China is currently the world's leading investor in renewables (Bloomberg, 2015). This public and private investment is predicated on the assumption that it will simultaneously benefit the environment, society, and economic competitiveness. The extent to which this assumption holds is, however, not clear. Therefore, there is a need to find empirical evidence on the merits or otherwise of the huge funds committed by the investors to renewable energy deployment from a firm-level perspective.

Here let me stress that I am not directly testing Michael Porter's Hypothesis because his hypothesis is narrowly conceded in the sense that 'pay' means profitable in terms of monetary outcomes. I argue that this is not an adequate definition of what pay is. If we change the definition of payoff, we can test it differently, which is a significant contribution. While investigating the whole issue in the context of China, we should notice the distinct features of state-owned enterprises (SOEs) and private-owned firms. Their perceptions of payoff may be different and vary over time. However, little attention has been paid to the definition of payoff. Thus, this research also seeks to interrogate the following questions: Who defines payoff? How do private companies and SOEs perceive payoff? Does their measurement of payoff incorporate things besides profitability?

This study chooses the electricity generation industry as the empirical illustration for two reasons. First, China's electricity sector, the single largest emitter of greenhouse gases in the world, is the decisive area of efforts to tackle climate change (L. Brandt & Rawski, 2019; Zou & Wang, 2018). To address the challenge, China has pledged to a low-carbon transition of the power sector. There has been a structural transformation over the past decade: the growth in the renewable generation has surpassed generation from fossil fuels, and the newly installed renewable capacity has taken up more than 20 per cent of the global electricity capacity (IEA, 2019; IRENA et al., 2018). It is thus surprising how little evidence is available associating the Chinese generators' green practices and financial performance. Second, although SOEs still dominate the generation sector, private firms actively participate in renewables that own half of the industry's solar facilities (IEA, 2018). Thus, the power sector is a particularly interesting site to interrogate the meaning of payoff defined by SOEs and private generators.

Both qualitative and quantitative methods were used in the investigation. Using mixed methods provides a way to offset the drawbacks of using monomethod and highlight the advantages of using both approaches (Creswell & Plano Clark, 2018; Tashakkori & Teddlie, 1998): qualitative methods stem from the interpretive tradition and are helpful to generate a rich understanding of a particular topic, however, their findings are often specific to the limited number of samples at hand causing the problems of generalisation (Bryman & Bell, 2015; Watkins & Gioia, 2015); quantitative methods seek to understand the breadth of the research topic while fails to capture the voices of participants, omits the context in which the research targets live and excludes emergent findings (Bryman & Bell, 2015; Creswell & Plano Clark, 2018). Therefore, this study integrates qualitative and quantitative methods to 'more thoroughly investigate a phenomenon of interest' (Teddlie & Tashakkori, 2010, p. 10). A quantitative method comprising longitudinal design and multilevel analysis was deployed to test the relationship between the generators' financial performance and the deployment of renewables. Qualitative analysis of semi-structured interviews, conducted with key actors during field research in two provinces in central and north-eastern China, was carried out to capture participants' perceptions of payoff to complement and enrich the quantitative results.

This research contributes to the existing research on 'does it pay to be green' in four ways. First, it provides new empirical evidence of the link between business green practices and performance by studying electricity generation firms in China and sheds light on the effects of the global trend of transition from the fossil-fuel provision system to renewable energy. Second, it builds on the most recent data, which is a decisive aspect given the fast-paced growth of wind and solar photovoltaic (PV) power. Third, it adopts mixed methods, which have not been widely used in the business and management field (Molina-Azorin, 2012; Molina-Azorín & López-Gamero, 2016), especially for this issue. Fourth, it takes careful consideration into different perceptions of payoff by SOEs and private firms, thereby enlarging the definition of payoff.

The remainder of this article begins by reviewing the literature on whether a firm can get commercial benefits from being environmentally friendly. It then presents the research design, the data and the models used. The following section presents empirical results and discussions. Section 5 concludes the article with implications and recommendations.

5.2 Literature review

The debate on whether it paid to be green started in the early 1970s, with the pioneer study by Bragdon and Marlin (1972). They refuted the conventional view of incompatibility between corporate environmental initiatives and corporate profitability after comparing 17 pulp and paper companies' pollution-control records to profits records. Their work attracted great interest in examining the association between corporate environmental-social performance and financial performance. Interests in this issue have been gaining momentum since the 1990s, when the importance of combating climate change was raised in the first climate meeting of the United Nations in 1992. The role of business since then has been considered essential to environmental issues. Many economists, notably Porter and van der Linde (1995), stipulate that better environmental performance could enhance firms' value. Some researchers reviewed the existing empirical studies, either by the vote-count technique (Horváthová, 2010; Margolis & Walsh, 2003) or through meta-analysis (Albertini, 2013; Dixon-Fowler et al., 2013; Endrikat et al., 2014; Orlitzky et al., 2003), and demonstrated that previous studies supported the position that 'it pays to be green'. Appendix I presents a general review of empirical studies published after 1995.

In the studies reviewed here, the way to capture environmental performance is diversified. Some studies used event studies to evaluate the financial market's response to the announcement of environmental events. The effects of positive environmental announcements on stock returns are mixed. Studies in the 1990s tend to show that the stock market rewards environmental initiatives (Klassen & McLaughlin, 1996; Yamashita, Sen, & Roberts, 1999), while studies after 2000 tend to show no impacts (K. M. Gilley, Worrell, Davidson, & El–Jelly, 2000) or even negative impacts on firm value (Fisher-Vanden & Thorburn, 2011; Jacobs, Singhal, & Subramanian, 2010; Lioui & Sharma, 2012; Pätäri, Arminen, Tuppura, & Jantunen, 2014). On the other hand, studies that examined adverse environmental events generated a similar conclusion that the market penalised those violating environmental rules (Godfrey, Merrill, & Hansen, 2009; Karpoff, John R. Lott, & Wehrly, 2005; Klassen & McLaughlin, 1996). Event studies could picture how the market views a specific corporate environment-related event within a narrow time frame; however, environmental disclosures and announcements could not be equated with corporate environmental performance (Clarkson, Li, Richardson, & Vasvari, 2011; King & Lenox, 2001).

Using scores such as the Environmental, Social and Governance (ESG) ratings generated by rating agencies is also a common way to measure environmental performance. Before 2016, some researchers used the ratings to construct portfolios and showed that ‘green’ (White, 1996) or ‘eco-efficient’ (Derwall, Guenster, Bauer, & Koedijk, 2005) portfolios outperformed the market. Others used the ratings to build a social or environmental index and confirmed a positive relationship between environmental and financial performance (Hull & Rothenberg, 2008; Russo & Fouts, 1997; Wagner, 2010). However, as these rating databases only include firms in the United States, the research coverage was limited to American firms. After 2016, more studies choose the ESG disclosure from Bloomberg or Asset4 from Thomson Reuters as the proxy for corporate environmental performance (Ait Sidhoum & Serra, 2017; Chopra & Wu, 2016; Gupta, 2018; Ibikunle & Steffen, 2017; Martí-Ballester, 2017; Zhi Wang, Reimsbach, & Braam, 2018). Such studies are based on a large sample of firms worldwide, and the results are mixed. The third-party rankings offer multiple dimensions of environmental and social performances; however, they are questioned for measuring the performance ‘on the basis of perceptions…not what the firm has actually done’ (J. J. Griffin & Mahon, 1997, p. 14). Again, a limited number of Chinese electricity firms involve in ESG ratings.

Another widely used measurement of environmental performance is the emissions of toxic chemicals. Compared with the ranking index, it measures the firms’ environmental actions based on hard data. The majority of studies in the 1990s and 2000s showed that emission reduction had negative (Cordeiro & Sarkis, 1997; D. L. Levy, 1995; Wagner, Van Phu, Azomahou, & Wehrmeyer, 2002) or no impacts on firms’ financial performance (King & Lenox, 2001). While studies conducted after 2010 largely showed reduced emissions (Clarkson et al., 2011; Qi et al., 2014), particularly the reduction of greenhouse gases (Iwata & Okada, 2011) or carbon dioxide (Busch & Hoffmann, 2011; Fujii, Iwata, Kaneko, & Managi, 2013), could enhance firm value.

In response to the climate urgency, the rapid uptake of renewables has drawn researchers’ attention to assessing the economic effects of firms’ renewable energy activities. Shin, Ellinger, Nolan, DeCoster, and Lane (2016) studied top renewable energy-user firms in the United States and found they outperformed their industry competitors. Similarly, Martí-Ballester (2017) investigated the renewable energy consumption of multinational companies from 36 countries and found that the adoption of renewable energy systems improved firms' short-term financial performance. Ruggiero and Lehkonen (2017) studied the amount of renewable energy produced by electric utilities and found that an increase in renewable power penetration negatively impacted their financial performance. Seng and Vithessonthi (2017) examined the renewable energy intensity of non-financial firms in the Netherlands and got mixed results using different financial indicators. These studies attempt to link financial performance with the specific measure of environmental performance in the energy transition context. My study examining the relationship between the electricity generators' deployment of green energy and financial performance is part of this strand of the literature.

Three issues emerge from the studies discussed so far. First, a relatively small body of literature is concerned with the green practices of firms based in developing countries, which can be explained by the inconvenient fact of the unavailability of databases. However, the ratification of the Paris Agreement in 2015 changed the paradigm of international climate governance. Developing countries, such as China, India and Brazil, are no longer exempt from the Toyoko Protocol's legal requirements of cutting down greenhouse gas emissions (Christoff, 2016) and are on an irreversible pathway to a green transition. Therefore, we need new empirical evidence on whether the developing countries could enhance their competitiveness by being green, thereby shedding light on under what circumstances we can achieve a 'just transition' (UNFCCC, 2015).

Second, despite the essential role of power sector played in the economy and in tackling climate change, which is recognised in a number of analyses of the differential impact of pollution by industry (L. Brandt & Rawski, 2019; IRENA, 2019; IRENA et al., 2018), studies conducted on the effects of green investment on the environmental and economic performance of electric utility firms are scarce. Only five out of these 54 reviewed studies examine the association between economic performance and environmental performance in the electricity industry (Ait Sidhoum & Serra, 2017; Filbeck & Gorman, 2004; Kroes, Subramanian, & Subramanyam, 2012; Ruggiero & Lehkonen, 2017; Sueyoshi &

Goto, 2009). Only Ruggiero and Lehkonen (2017) investigate the specific aspect of electricity generators' environmental performance: the deployment of renewable energy in power production. The adoption of renewables can improve utilities' environmental performance. However, the question is whether it pays off in economic terms, which is a timely question in light of the fact that a vast majority of utilities have not grown their portfolios of renewables at all over the past two decades (Alova, 2020). In this context, this study contributes to the 'does it pay to be green' debate by proposing the specific measurement of 'green' – renewable energy intensity – in respect of examining the effects of green transitions in the power sector.

Third, previous studies have not treated payoff in much detail. In all the studies reviewed here, no attempt has been made to interrogate who defines payoff and how the corporate decision-makers perceive payoff, despite their perceptions of payoff would directly affect the investment and management of the renewable energy projects. Thus, this study seeks to fill the research gap by adopting mixed methods. The vast majority of studies on this issue have been quantitative. Though adopting the quantitative approach can help us form generalisation, the voices of participants can hardly be captured if we rely on statistical data alone (Bryman & Bell, 2015; Creswell & Creswell, 2018). Therefore, through conversations with corporate managers, this study further explores how the firms, both state-owned electric firms and private generators, define payoff and thereby contributes to the literature by enlarging the definition of payoff.

5.3 Data and methodology

5.3.1 Research design and data

The design of this mixed methods research is a two-phase exploratory sequential study in the context of a single industry. Two provinces located in the middle and north-eastern China were chosen as the research settings, primarily because of the prior personal contact making these two regions accessible. The GDP per capita of these two provinces is lower than the national average. Their electricity industry is powered primarily by coal and gradually incorporating renewables into their incumbent fossil-fuel power provision system. Wind and solar PV power are the leading renewable energy sources in these two provinces and have been installed since 2005. State-owned power generation firms (SOEs) take up more than 80 per cent of the whole electric sector in these two regions, dominating the region's coal-fired power market and wind power market. Private firms actively participate in solar PV and plain-low-speed wind power projects.

5.3.1.1 Stage 1 Qualitative research

The first stage of the study involved case studies through in-depth semi-structured interviews. The interviewees were chosen for their different perspectives and particular expertise. All of them have worked in the industry for more than ten years. The main participants are managers of electricity generation companies. Same questions were asked, and the findings were compared to investigate the 'what' and 'how' questions. Each interview lasted from 45 minutes to 1.5 hours and was audio-recorded with permission and then transcribed and translated into English. Supplementary interviews with other participants in the industry were carried out simultaneously, providing a rich description of the research problems. Participants are managers of the Project Planning and Development Department of the local State Grid companies, representatives from the local National Development and Reform Commission, and managers of the Corporate Banking Department of the local commercial banks.[34] By communicating with the participants in person, a good rapport with interviewees was established, making the corporate data accessible. The exploration phase increases the feasibility of data collection and, more importantly, provides participants' insights and explanations of the changes that happened within the firms. The qualitative materials facilitate the interpretation of the statistical results and further give the quantitative findings practical explanations and significance.

[34] In total, 31 interviews are conducted, including 14 state-owned generators, six private generators, five government authorities, two managers from local grid firms, and four banks. Interview subjects are referenced anonymously, with Cs for the state-owned electricity generator, Cp for the private generator, B for the local bank, G for the local government, R for the grid firm.

5.3.1.2 Stage 2 Locating variables for quantitative research

Measurements for corporate environmental performance and financial performance were identified in the exploration phase. As mentioned above, this study focuses on examining the firms' renewable energy activities, and after contact with local generators, data on their electricity capacities by energy sources are accessible. Thus, referring to the previous studies on renewable energy activities (Escobar & Vredenburg, 2011; Martí-Ballester, 2017; Ruggiero & Lehkonen, 2017; Seng & Vithessonthi, 2017; Shin et al., 2016), this research adopts renewable energy intensity – the ratio of total electricity generated from renewable energy sources to the total energy – as the proxy for corporate green efforts.

There are two streams of measuring the firm's financial performance: accounting measures represented by various financial ratios (S. L. Hart & Ahuja, 1996; Horváthová, 2012; D. L. Levy, 1995; Seng & Vithessonthi, 2017; Wagner et al., 2002), and market-based measures (Y. Chang, Fang, & Li, 2016; Dowell, Hart, & Yeung, 2000; King & Lenox, 2001; Lioui & Sharma, 2012; Wagner, 2010). An increasing number of studies question the short-term nature of financial ratios and prefer market-based measures, which are forward-looking based on future expected performance (Wagner, 2010). In this case, Tobin's q, which is a ratio that measures the market value of a firm relative to the replacement value of its assets (Tobin, 1969), is the most favoured measurement to reflect the intangible value of a firm's environmental initiatives and the expected future gains (Dowell et al., 2000). Nevertheless, Sueyoshi and Goto (2009) highlighted that though Tobin's q is an important measure of a firm's corporate value, it exclusively measures a firm's market value at a holding company level. In contrast, this research is interested in measuring the performance of firms that are subsidiaries of the holding company. Accordingly, Tobin's q is not an appropriate indicator for this research. Return on Assets (ROA) – the proportion of earnings before interest and tax to total assets – is the selected proxy to indicate the profitability of electricity generation firms relative to their total assets.

5.3.1.3 Stage 3 Quantitative research

The third stage of research involved quantitative methods comprised of longitudinal design and multilevel models for the analysis of longitudinal data. The sample includes 25 state-owned local generators covering the period of 2005 to 2017. Although private firms have been contacted and interviewed, they either refused to provide financial and operating data or could only offer one to two-year data as they newly established. The merits of longitudinal design are that it allows the separation of cross-sectional and longitudinal effects and allows the investigation of heterogeneity across units in the overall level of the response over time (Skrondal & Rabe-Hesketh, 2008). Longitudinal data have a hierarchical structure, with repeated observations over time (level 1) nested within individuals (level 2) (Steele, 2008), which can be analysed with multilevel models. Multilevel models are appropriate to analyse the repeated measures data on transformed firms in this study for two reasons: the flexibility of dealing with unbalanced data structures (Snijders & Bosker, 2012) and the capability of assessing change and the growth of the firm (Van Der Leeden, 1998). Most of the firms experienced corporate reorganisation and asset reorganisation, causing missing data in the early years of the current accounting and financial system. Given the incompleteness of the data, multilevel analysis was recognised as the most favourable method because it did not require balanced data and could include incomplete cases (Snijders & Bosker, 2012; Van Der Leeden, 1998). Moreover, the longitudinal multilevel model could take into account individual growth and describe the expected values of the observations as functions of time.

5.3.2 Data analysis

5.3.2.1 Qualitative analysis

The analysis process began while the interviewing was still underway. During the interviews, audio-recording together with notetaking was used to record the information acquired through interviews. The interview note was assessed through thematic analysis of reoccurring constructs. For each interview, the specific ideas of the interviewees were noted and then sorted out to see which ones were important, which ones were common or rare, and how they related to others. After completing each interview, a summary note was completed to highlight emergent themes and other issues of interest, which was then followed up at subsequent interviews.

After collecting all oral evidence, a more detailed and fine-grained analysis of interview transcripts was conducted. The analysis process is the same as that in Chapter 3. Specific words and sentences repeated frequently or sound different from the ordinary vocabulary were labelled, together with the emergent themes aroused from the preliminary analysis, to generate the main themes. Then commonalities and differences of causes and consequences were located through constant comparisons. When the interviewees' answers to the same question contained contradictory implications, testimony from the third party, including the government authorities and commercial banks, was used to provide further evidence for the controversial interpretation.

5.3.2.2 Quantitative analysis

Two-level models, in which longitudinal measurements nested within firms, were estimated. ROAs were standardised, and renewable energy intensity (re%) was categorised as low (0-14.99%), medium (15-39.99%) and high (40-100%). The year 2013, when the Beautiful China Scheme was initiated, was set as the reference point. Reference value for time, denoted by yr_{13}, $t = year_n - yr_{13}$ (n=2005, 2006,..., 2017). Growth curves plot these trajectories as a function of time. The analysis was carried out by using MLwiN (Rasbash, Steele, Browne, & Goldstein, 2020).

Before doing any modelling, a preliminary analysis was carried out by plotting ROA on each occasion for firms. Appendix J shows the results of the exploratory study indicating non-linear changes among firms. Thus, it suggested that using a polynomial function (time, $time^2$, $time^3$) in models would be able to trace the growth of the firm over time. This assumption was tested using the log-likelihood ratio test statistics. Growth curve models were applied in the analysis of changes that happened in the firms. Let ROA_{ij} be the measurement for individual firm j at occasion i. e_{ij} is an occasion level error with a normal distribution; mean zero, and variance σ_e^2. The ROA_{ij} of firm j at accession t can be modelled as a cubic polynomial function of time (denoted by t). μ_{0j} is a random effect, allowing the intercept of the trajectory to vary from firm to firm. μ_{kj} is a random effect, allowing the linear term in the cubic function of time to vary, thus changing the shape of the cubic curve from firm to firm.

$$ROA_{ij} = \beta_{0ij} + \beta_{1j}\, t_{ij} + \beta_2\, t_{ij}^2 + \beta_3\, t_{ij}^3 + e_{ij}$$

$$\beta_{0ij} = \beta_0 + \mu_{0j} + e_{0ij}$$

$$\beta_{kj} = \beta_k + \mu_{kj},\ k=1$$

Where $var(\mu_{kj}) = \sigma_{\mu k}^2$, $cov(\mu_{kj}, \mu_{k'j}) = \sigma_{\mu kk'}$, $k \neq k'$

After testing non-linearity in ROA, it then tested for interactions with different types of renewable intensity by adding the explanatory variable renewable energy intensity. It was denoted by re and declared as a categorical variable, as re_1 for low re%, re_2 for medium re% and re_3 for high re%. Low re% (re_1) is the baseline category. Thus, the cubic growth model can be formulated as

$$ROA_{ij} = \beta_{0ij} + \beta_{1j}\, t_{ij} + \beta_2\, t_{ij}^2 + \beta_3\, t_{ij}^3 + \beta_4\, re\_2 + \beta_5\, re\_3 + e_{ij}$$

It further added a cross-level interaction between time and re% (re_2) to explore whether the renewable energy effect on ROA changes over time. This yields the model

$$ROA_{ij} = \beta_{0ij} + \beta_{1j}\, t_{ij} + \beta_2\, t_{ij}^2 + \beta_3\, t_{ij}^3 + \beta_4\, re\_2 + \beta_5\, re\_3 + \beta_6\, (re\_2 * t) + \beta_7\, (re\_2 * t^2) + \beta_8\, (re\_2 * t^3) + \beta_9\, (re\_3 * t) + \beta_{10}\, (re\_3 * t^2) + \beta_{11}\, (re\_3 * t^3) + e_{ij}$$

5.4 Results and discussion

The results of the ROAs of the longitudinal data with 13 repeated measures are shown in Table 5-1. Results from a series of likelihood ratio tests of the variation in growth rates of corporate ROA are presented in the table. Model 1 is the simple variance components model, which is the baseline model. In Model 2, only the intercept is permitted to vary, and Model 3 adds individual variance in the linear term β_{1j}. Results are calculated using the maximum likelihood estimation procedure. Comparing the deviance of Model 2 and 3 shows that the random slope of time is significant. It indicates that there is a significant deviation from the random intercept model. Model 5 extends the previous model by allowing the cubic effect to vary across individuals. The fit is much better than that of the linear model, with a deviance difference of 63.097 for 2 degrees of freedom. The random effect of the cubic term is significant. A cubic model turns out to yield a much better statistical fit than the linear model.

	Model 1, null simple variance components model		Model 2 random intercept model		Model 3 linear random slope model		Model 4 quadratic model		Model 5 cubic polynomial model		Model 6 5+type		Model 7 6+poly(yr13)*type	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Response	ROA		ROA		ROA		ROA		ROA		ROA		ROA	
Fixed Part														
β_{0ij} (cons)	0.016	0.096	0.066	0.095	0.061	0.090	0.015	0.101	0.358	0.107	0.327	0.141	0.598	0.147
β_{1j} (t)			0.055	0.017	0.061	0.022	0.074	0.025	0.232	0.030	0.260	0.034	0.372	0.041
β_{2j} (t^2)							0.005	0.005	-0.049	0.008	-0.054	0.009	-0.089	0.011
β_{3j} (t^3)									-0.011	0.001	-0.012	0.002	-0.018	0.002
β_4 (re_2)											0.029	0.283	-0.423	0.345
β_5 (re_3)											0.115	0.199	-0.496	0.232
β_6 (re_2*t)													-0.142	0.175
β_7 (re_2*t^2)													0.049	0.035
β_8 (re_2*t^3)													0.003	0.012
β_9 (re_3*t)													-0.296	0.068
β_{10} (re_3*t^2)													0.088	0.017
β_{11} (re_3*t^3)													0.016	0.003
Random Part														
Level 2: firmj														
Var(cons)	0.144	0.065	0.136	0.062	0.120	0.058	0.122	0.058	0.141	0.058	0.141	0.062	0.148	0.061
Covar(t/cons)					0.000	0.010	-0.001	0.010	0.000	0.009	0.003	0.011	0.006	0.010
Var(t)					0.005	0.003	0.004	0.003	0.004	0.003	0.005	0.004	0.004	0.003
Level 1: occasion														
Var(cons)	0.860	0.079	0.827	0.076	0.773	0.074	0.771	0.074	0.588	0.056	0.636	0.066	0.546	0.057
Units: firmj	25		25		25		25		25		25		25	
Units: occasion	264		264		264		264		264		264		264	
-2*loglikelihood:	734.464		723.822		718.148		717.097		655.051		590.098		557.183	

Table 5-1 Results of comparing different growth curve models fitted to corporate ROA, 2005-2017

5.4.1 Adopting renewables have a positive impact on ROA

After adding the explanatory variable re% (model 6), the statistical result (see Table 5-1) shows that re% (re_2) is positively related to ROA. A plot of the growth curves for the studied firms against time is shown in Figure 5-1.

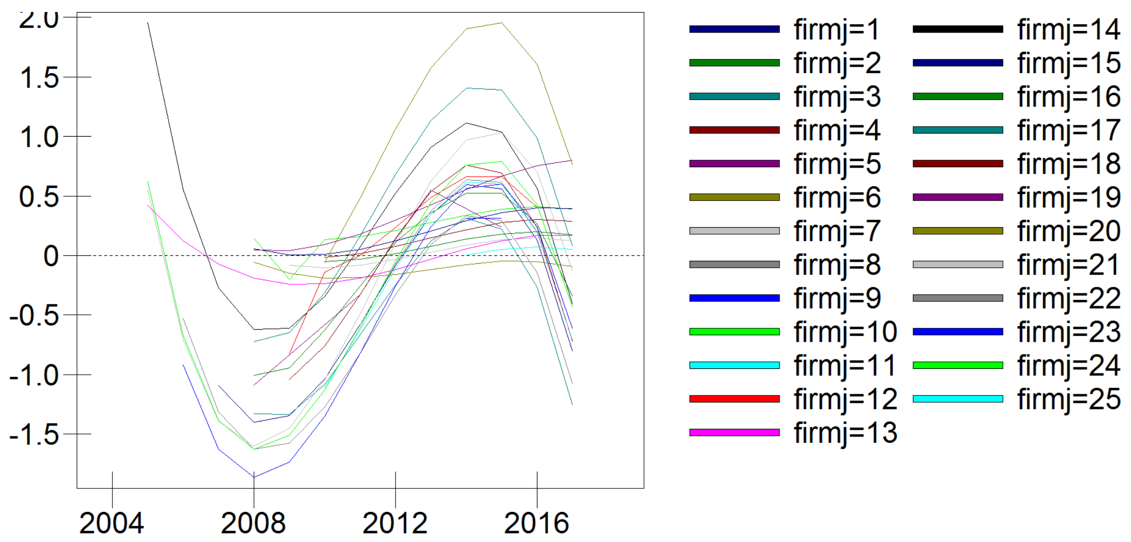

Figure 5-1 Growth curves for 25 local generators from 2005 to 2017

The cluster of curves in the middle part of the figure represents firms with high re%. Wind power is the dominant renewable energy in the studied firms. Although they share a similar trend, it can be seen from Figure 5-1 that the differences between them are gradually increasing. It is interesting to note that Firm 6, 15, and 19 had the similar ROA at the beginning, they have a similar total capacity (around 1,500 MW), all on-grid in 2018 and belong to the same power-generating conglomerate; however, their financial performance started to diverge over time. At the end of 2017, the ROA of Firm 19 increased to 5.73, Firm 15’s ROA was 3.03, while the ROA of Firm 6 was 1.04, 4.69 lower than that of Firm 19. They are all wind power generators; however, Firm 6 and 15 are located in north-eastern China, and Firm 19 is in central China. In terms of resource endowment, the north-eastern province has abundant wind sources, making it one of China’s major wind energy bases. However, the generators in the northeast have experienced massive curtailment of wind power since 2013. The region’s curtailment rate of wind power was 14.6 per cent in 2013, increased to 21 per cent in 2015, and maintained high in 2016 (19 per cent) and 2017 (15 per cent). It is the primary reason why the profitability of wind power companies in the north-eastern province is generally lower than those in the central region, where no wind curtailment exists. The power industry in the north-eastern province has faced serious over-capacity problems since 2010 due to long-lasting industry depression and increasing population outflow. Besides, the winter in this area lasts for half a year, and combined heat and power (CHP) units are required to meet the heating demand, which has already accounted for most of the electricity generation, leaving a small share of power generation for renewable energy. When asked the region's grid firm, which is in charge of electricity transmission and distribution, the reason for the persistent high curtailment rate, the participant said,

> For us, there is no technical problem as we have the most advanced transmission line already; neither the economic conflicts between absorbing coal-fired power, nor wind power integration, as we pay the same price to any generators. However, our only task, or in a more fashionable term 'social responsibility', is to ensure the grid's stability whilst ensuring low electricity prices for residents, which could only be fulfilled by coal-fired power generation at present. (Interviewee R2, December 2018)

Figure 5-1 also shows the development of coal-fired power plants. The two curves at the top (Firm 20) and bottom (Firm 23) represent two coal-fired power plants located in central China. Compared with Firm 23, Firm 20 is a pithead power plant located in a city abundant in coal resources with excellent geographical position and transport facilities. Firm 23 was established in 2004 with one subcritical unit, which was upgraded to combined heat and power (CHP) in 2010, and two supercritical (SC) units installed in 2011. Firm 20 has two subcritical units (built in 1995), two SC units (installed in 2006), and one ultra-supercritical (USC) unit (on-grid in 2016).[35] The subcritical units have completed depreciation and paid off the loans in 2008. 'Without financial expenses, the subcritical units are the most profitable of all units. As long as these units are allowed to generate electricity, they are purely profitable', said the manager in Firm 20 (Interviewee Cs20, January 2019). In 2016, the 300MW unit was upgraded to CHP, which fully operated with a high load factor during winter. In comparison, the advanced units are under-utilised, especially the USC unit only being used for deep peaking (low loading) (Interviewee Cs20, January 2019). The

[35] The firm was established in 1995; however, the data is only available from 2010 onwards as the previous records are not digitalised and sealed.

coal price started to increase again in 2016, the subcritical units were the only profitable units in 2016 and 2017, with a profit of CNY30 million in 2017, the yield of the SC units was around zero, and the USC unit was at a severe loss with around CNY100 million depreciation and financial expense per year (ibid). Besides, the government issued mandatory provisions requiring the coal-fired power plants to retrofit, meet the emission standards and install the monitoring system (NDRC, NEA, & MEP, 2014b; StateCouncil, 2014b, 2015b). The abatement costs account for the main part of the retrofitting expense, of which about CNY200 million for installing flue gas desulphurisation (FGD) and selective catalytic reduction (SCR) equipment and CNY20 million for enclosing the coal yard (Interviewee Cs7 & Cs23, 2018; Cs20, 2019). Thus, the increasing coal price, underutilisation of the advanced coal generation facilities, and high retrofitting costs caused the local coal-fired power generators' profits to continue to fall from 2015 to 2017. It is expected that the low profitability of coal-fired power plants will persist for the long term (Interviewee B1, Cs1, Cs7, Cs8, & G1, 2018; B2 & Cs20, 2019).

5.4.2 Firms grow faster with higher shares of renewables

Model 7 adds a cross-level interaction between time and re% category to explore this. The corresponding results (see Model 7 in Table 5-1) show strong evidence that the growth rate differs by re%. ROA of high-re% firms grows faster than that of low-re% companies. Figure 5-2 illustrates the mean ROA for each re% category plotted against time. As can be seen from the figure, the mean ROA of firms with high re% is more stable than those with low and medium re%. Besides, firms with low and medium re% shared similar trend, and the differences between them are small. Furthermore, the ROAs of high-re% firms tend to increase, contrasting with the decreasing tendency of ROAs of low and medium re% firms after 2015. It indicates that after 2015 the growth rate of companies whose renewable energy accounted for less than 40 per cent declined significantly, while the generators with renewables accounted for more than 40 per cent maintained continuous growth and significantly outperformed others.

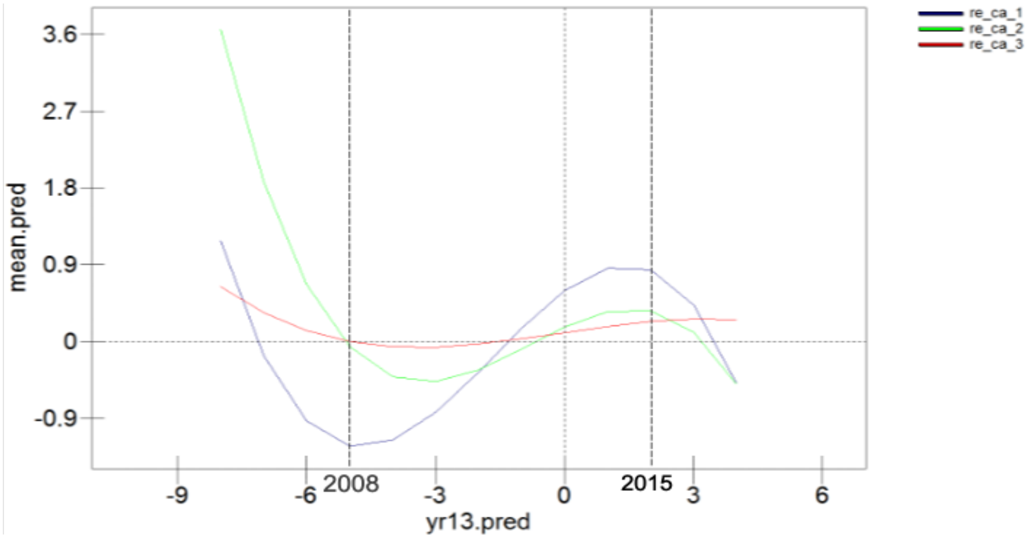

Figure 5-2 Mean ROA by re category

It can also be seen from Figure 5-2 that 2008 and 2015 are two turning points. The leading cause of the dip in 2008 was the drop in electricity demand caused by the 2008 financial crisis. Moreover, the frequent coal mine accidents in northern China led to the shortage of coal resources and the rise in coal prices. Natural disasters such as earthquakes and blizzards in the south that year led to rising costs of construction materials such as steel and cement. Therefore, the power generation industry suffered tremendous negative impacts in 2008, especially coal-fired power generators. On the other hand, companies that use renewable energy to generate electricity are less affected by such risks. The cost of wind turbines increased in 2008 because of the increasing prices of raw materials (CEC, 2007-2017). However, the impact on corporate profitability is not significant because 2005 to 2011 is the golden period of China’s wind power sector,[36] which explains why the high-re% curve in Figure 5-2, mainly composed of local wind power generators, experienced a slight decline in 2008 and then a sustained growth.

The other turning point is 2015; since then, the ROA of electric firms with low and medium re% has continuously declined. In 2015, China’s new Environmental Protection Law was effective, establishing a strict fine system for polluting firms. Meanwhile, the central government announced a new Electricity Reform

[36] Along with the establishment of China’s Renewable Energy Law in 2005, domestic wind farms started to emerge and peaked in 2010 and 2011 (ChinaElectricityCouncil, 2018).

(StateCouncil, 2015a) and started to implement National Energy Plan (StateCouncil, 2014a), giving high priority to increasing the utilisation of renewables (NDRC & NEA, 2015c, 2016a). At the same time, the coal price started to grow. The local coal-fired power plants were urged to speed up retrofitting regardless of the cost. The focus of economic development shifted from high energy-consuming industries to high-tech and service industries, causing the underutilisation of advanced coal-fired power plants. Therefore, electric firms that relied on coal suffered severe losses while renewable energy projects began to highlight their advantages when facing strict environmental and industrial policies.

5.4.3 Meaning of payoff: profit and growth

As mentioned earlier, due to the data limitation, the statistical analysis was based on a sample of local SOEs, and the renewables they incorporated in the portfolio are primarily powered by wind. Nevertheless, it is worth noting that the crucial role private firms played in the renewable energy sector. Private-owned generators led the solar PV power market, were the first movers of the low-speed wind farms in C-province and were the primary players in the province's biomass power generation. One interesting finding from the interviews with these two types of generators is that their perceptions of pay are different and have changed in the past decade (summarised in Table 5-2).

	Before 2013		**After 2013**	
	Payoff	Outcome	Payoff	Outcome
SOEs	Generating capacity	Fast growth without profit	Profit	Slow growth with profit
Private solar PV power generators	Profit	Slow growth with low profit	Political power, Market share	Fast growth with profit
Private wind power generators	Optimising technological proficiency	Steady growth with stable profit	Optimising technological proficiency	Fast growth with competitive profit
Private biomass power generators	Profit	Slow growth with low profit	Optimising technological proficiency	Slow growth with promising profit

Table 5-2 Changing key perceptions of payoff and the corresponding outcomes

The socialist system has a preference for pursuing mere size (Wiles, 1962, p. 304), which is recognised as a result of ‘investment hunger’ – a phenomenon noted by Kornai (1992) that universal shortages of goods made every developing country an impatient ‘late arriver’ and thereby unlimited appetite for investment (pp. 161-162). In China, the ‘investment hunger’ started from the ‘Great Leap Forward’ in Mao Zedong’s era and persisted even there is no excess demand (Rawski, 2019). SOEs used to exist in the form of branches or affiliates of government departments. In 2003, the State-owned Assets Administration and Supervision Commission (SASAC) was established to act as the owner and investor on behalf of the state. SASAC is in charge of SOEs’ restructuring, asset appraisal, performance assessment, financial supervision and administration of state-owned assets (Sheng & Zhao, 2012). Until recent years, total capacity had been the primary criterion for assessing the performance of SOEs. Total generating capacity was SOE’s primary perception of payoff. Thus, SOEs pursued large-scale generation projects, such as coal-fired power plants and hydropower stations, regardless of costs and profits.

Plotting the mean ROA of the sample against time (see Figure 5-3) shows that although the deployment of renewable energy could enhance profitability, SOEs continued pursuing new coal-fired power generation projects in the face of negative profits from 2008 to 2011. It indicates the non-commercial nature of their investment decisions. Generators view their expansion as ‘staking a claim’ (Gao & Wang, 2011) to future delivery quotas (Interviewee Cs1, 7, & 11, 2018). However, such ‘blind expansions’ in coal-fired power (before 2015) (Yuan, 2016, p. 36) and ‘Great Leap-style’ overinvestments (B. Li, 2016) in wind power (before 2013) and solar panel manufacturing (before 2012) brought an ‘inflated’ (S. Fan, 2016, p. 8) growth of SOEs.

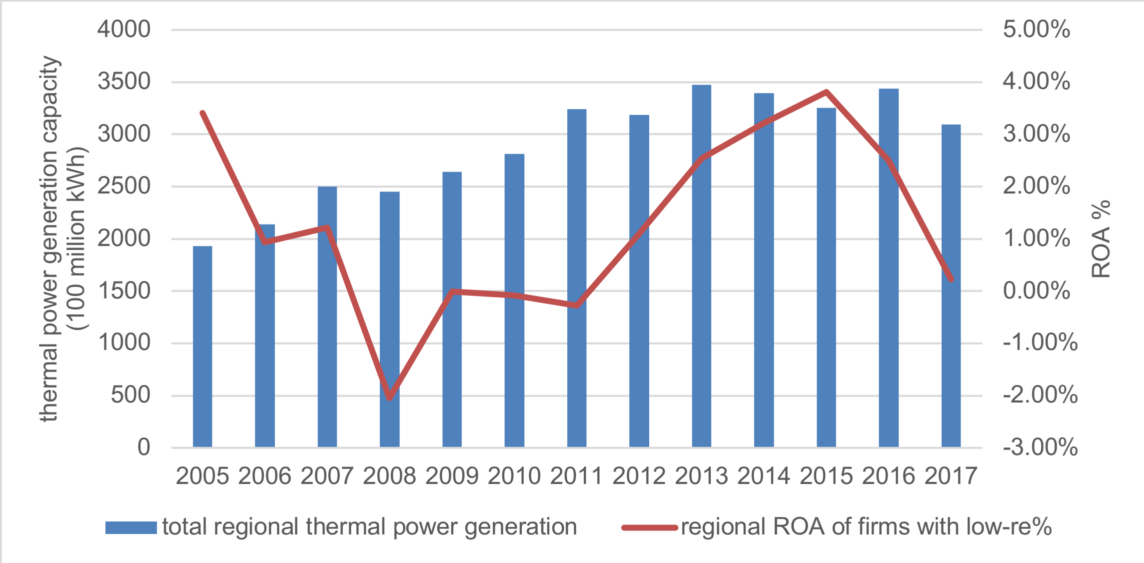

Figure 5-3 Profitability of the regional electric generator vs regional thermal power generation capacity, 2005-2017

The problem of 'growth without profits' has been rightly noticed by the new leadership of the Chinese communist party since 2013. A new round of SOE reform was promoted, emphasising being 'stronger, better and bigger'. It also stressed the fixed sequence: stronger is the basis of being better, and stronger and better are the basis and guarantee of being bigger (Zeng, 2016). Since then, SOEs have gradually replaced scale with profit as their measurement of pay. For example, since 2013, Huaneng, one of China's big five generators, put 'increasing profitability' and 'increasing economic efficiency' as the top priority in its annual work conference report.[37] Thus, the SOEs are striving for not only 'producing for the public' but also 'making money for the public' (Interviewee Cs1 & 15, 2018). Regarding profitability as the major concern, the local SOEs have been cautious in investing in coal-fired power facilities and have begun to actively invest in renewable energy projects which have great profit potential.

The first solar PV power stations in these two provinces were private-owned built in 2012 and 2014. The private generators are also solar panel manufacturers. Like other participants in China's solar PV industry before 2009, their business was export-oriented, with more than 95 per cent of the panels exported to overseas markets. Achieving high profits was their only concern.

[37] More detailed annual working reports of Huaneng Group see H. Yang (2011) and Ha (2013, 2015, 2016).

However, when the European Union and the United States filed anti-dumping and anti-subsidy lawsuits against China's solar module manufacturers, their overseas market slumped. They experienced huge losses and barely survived. From 2009 to 2012, they lobbied the local government and alliance with the local authorities to draft and propose plans to expand the domestic market to the higher level of government (Interviewee G2, 2018, 2019; Cp2 & Cp5, 2019). Together with their counterparties in the industry, they established the Solar PV industry association to provide the government with suggestions for industry reform (Interviewee G1, 2018; Cp2 & G2, 2019). The private enterprises, at last, drove and shaped the policies and governance in the solar power industry. Since 2013, the central government issued a series of measures to support the expansion of the domestic solar power generation market, which propped up producers to absorb their productions. Through the vertical expansion of the supply chain, the solar panel manufacturers have also become solar power generators. They have consolidated their position in the solar PV industry and thus gained profits but also political power and prestige. To maintain their advantage in the SOE-dominant electricity industry, the private firms now value political legitimacy over profits. They believe that the technology is already economically attractive; they need to obtain more political power to be able to compete with SOEs in the electricity market and ensure that they can expand their market share and achieve sustainable growth (Interviewee Cp2, 2019; Cp3, 2018).

Private firms actively participate in the low-speed wind power market and have developed the region's first low-speed wind power farm. They are wind turbine manufacturers. They initially became generators to test their new wind turbine technology. Accompanied by the technology approaching maturity (around 2014), they improved their supporting power generation services and tried innovative financing products. Their ultimate goal is to provide an integrated solution for the low-speed wind power market (Interviewee Cp6, 2018). The manager of the region's first low-speed wind power farm said, 'we have a requirement to grow without too much consideration for profitability' (Interviewee Cp6, 2019).

The two provinces involved in this study are also important agricultural production provinces in China. A few small private biomass power plants were established to process wheat straw and corn stalks in the late 2000s when the government announced providing subsidies for biomass power generation. However, the profits were minimal, mainly because of the high cost and immature technology; there was little follow-up development. By visiting the region's only newly established biomass power start-up, I found that the firm is a biochemical firm that uses straws and corncobs to extract industrial furfuryl alcohol and then use the waste from the production process to generate electricity and heat. Through this model, they achieved a closed-loop, zero-emission, in the factory. They also negotiated with local authorities to sell the excess electricity and heat to the nearby villages. As of the end of the interview in early 2019, this start-up has been approved to build the region's first biomass CHP plant. As indicated by the manager, 'in the past, we only pursued profits which were short-term effects; now, we value technology innovation the most, which is the foundation of long-term growth' (Interviewee Cp1, 2019). In general, Chinese entrepreneurs in the power sector tend to have a growth imperative and value technology proficiency over profitability since the early 2010s. They shared the same belief with Porter and van der Linde (1995)' advocacy of 'innovation offset' that innovation could 'lead to absolute advantages over firms' (p. 98).

5.5 Conclusion

This study has investigated the long-lasting debate on 'does it pay to become green'. It situated the interrogation in the context of energy transition and evaluated the economic effects of adopting green energies. Based on the longitudinal multilevel analysis of a sample of local electricity generators in China over the 2005 to 2017 period, the statistical results showed that the deployment of renewable energy boosted the generator's profitability (expressed as ROA). Moreover, the profitability increased faster in firms with high shares of renewables in comparison with those with low percentages of renewables. The result also indicated that when the proportion of renewable energy was less than 40 per cent, the financial performance of the generators was similar: fluctuated with a decreasing trend; while when the ratio of renewables reached more than 40 per cent, the generators showed good resilience and increasing trend of the profitability. Furthermore, this study revealed that the central government led the assessment of SOEs and thereby determined how SOEs defined payoff. Based on intensive interviews with various participants in the industry, this study explored the meaning of payoff for the Chinese SOEs and private firms. The findings showed that their key perceptions of payoff varied over time: SOEs now strive for growing profits rather than mere size; entrepreneurs prioritise the advancement of technology and political status over the pursuit of pure profits.

The findings from this study make several contributions to the current literature. First, the electricity industry in the current era of the green energy transition is underexplored in the literature. Second, this study contributes to the literature by analysing the under-appreciated subnational green energy transition of the world's largest electricity generator and the top emitter of GHG. It advocates using renewable energy intensity to measure 'green'. This study has been one of the first attempts to adopt mixed methods to examine the linkage between the Chinese generators' financial performance and the deployment of renewables. In addition, it takes into account the distinguishing features of China's state-owned generators and private firms. In doing so, this study contributes to the debate concerning the definition of 'payoff'. The findings enhance our understanding of payoff and could be used to design new measurements of payoff for further studies.

In addition, these findings are relevant to both practitioners and policymakers as they have a number of practical implications. First, the results highlight the profitable growth for generators deploying renewables but also depict the pessimistic future of the coal-fired power business. Overbuilding, especially the advanced coal-fired generation facilities, causes the underutilisation of coal-fired power plants, depressing corporate profitability. In addition, high stranded assets threaten future profits. Thus, it suggests no new construction of coal-fired power plants, either for the sake of climate change or economic concerns. Also, it advocates that the developing regions that currently depend heavily on fossil fuels would be able to use renewables to reap strategic and economic benefits. As renewable technologies are developing rapidly and cost-efficient, the backward regions have a golden opportunity to avoid expensive fixed investments in fossil fuels and centralised grids by adopting mini-grids and decentralised solar and wind energy deployed off-grid. Especially under the Covid crisis, renewables have shown resilience to the crisis (IEA, 2020c), indicating significant potential for green recovery.

Furthermore, the results suggest a requirement for rapid transition from the perspective of the sustainable growth of the business. As it has been shown, when renewables account for more than 40 per cent of their total capacities, power generators can achieve long-term and sustained growth. On the other hand, the industry will experience some potential losses in the process of increasing the proportion of renewables from around 25 per cent[38] to 40 per cent. Therefore, for practitioners, the advantage of expanding fast in renewables is explicit right now; those who are becoming green faster than others could enjoy a superb performance. Policymakers need to acknowledge that relying on the industry alone could not achieve the rapid transition. Strengthening support for electricity storage technology guarantees the feasibility of large shares of renewable in the electricity network. Also, financial innovation is prerequisite and urgent. Existing financial products were designed for a large-scale centralised system. The decentralised nature of renewable power requires innovative financing tools to support the construction of the new network. The findings also suggest that the market and the government should welcome vigorous entrepreneurs to gear the local transition. The flexibility of the entrepreneurs is in line with the characteristics of distributed electricity; thus, it recommends introducing measures, such as financing support, education and knowledge exchange and on-grid coordination and facilitation, to support the development of local private generators.

This study still has some limitations. First, the statistical analysis did not include private firms. The lack of data from private electric firms has limited this study to comparing the effects of becoming green between SOEs and private firms. The renewable energy projects involved in the quantitative phase of analysis are limited to mountainous wind power farms. The solar PV and the plain wind

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[38] According to the energy database from IEA (IEA, 2020d), in China, the share of total renewables (including hydro, solar, wind, biofuel, tide and geothermal) in 2018 was around 24.7 per cent, and the share of wind and solar power was around 7.6 per cent.

power projects, which are actively promoted in the province, are not included in this study. Moreover, this study only studies two provinces in China, limiting the generalisation of the research results. Therefore, this study calls for future research to examine a diverse sample of companies. Replicating the current research incorporating data from private firms and various types of renewable energy projects may yield more robust findings.

Chapter 6 Conclusion

This thesis has set out to explore how might China green its power system. Hereby, becoming green means a process, a direction of the system’s development, and radical shifts to sustainable practices. Such a notion of green invites questions about the process and drivers of change. Three themed chapters were constructed to conduct the investigation.

6.1 Summary of the main research findings

Chapter 2 explores the origin of the Chinese power system and the forces that drive its growth and shape its style. Studying the industry's history presents us the opportunity to see how changes happened before, understand better what is happening today, and contemplate possible future actions. Using Hughes’s system approach and working through the material chronologically, I distinguished five periods in the system's evolution and identified the main driving forces in each stage of the system's growth.

The 1880s – 1953 are the formative years of the Chinese electric power system. The chief driver of the formation of the Chinese power system was unrelenting warfare. It was the invaders that brought electricity to China. Incessant wars forced China to undergo a scientific revolution. Modern natural science was acknowledged in China, and modern universities were created, which were the necessary conditions for the emergence of the Chinese power system. Students were sent abroad to study science and technology and then returned to China, establishing organisations on electrical sciences and engineering. While professionals had to rely on government funding for research and training, they tried to and were allowed to, due to the Nationalist government’s vision of China as an industrial state, maintain political neutrality, shielding the development of the national power system from the chaotic political movements of its early days. From 1953 to 1978, politics dictated the system’s development agenda. Maoism, the centralised-planned economic development model learned from the Soviet Union, and the Soviet technical aid all profoundly directed and influenced the progress of the system’s development.

The Reform and Opening policy launched in late 1978 abandoned the centrally planned economy and welcomed experimentations that could help unleash market forces, triggering overall economic growth that needed to be backed up with the power system's growth. However, as the system grew, financing became the 'reverse salient' in the 1980s, which fell behind the system's development and elicited financial innovations. After financiers corrected the reverse salient, the power system grew steadily and could meet economic growth needs. From 1997, attempts were made to reform the institutions to meet the growth of the system. However, the institutional 'reverse salient' could not be corrected within the existing system, leading to a new round of power sector reform.

During 2002 and 2015, the electricity market was restructured, and so were the regulatory agencies, together with constant industrial upgrading to meet the internal need of increasing energy efficiency and the external global environmental standards. Such radical changes in policies drove the Chinese power system to grow at an unprecedented pace and acquire momentum. After 2015, the climate emergency and the need to reconstruct the economy towards sustainability urged a fast green transition to the power system.

Comparing the pattern of evolution of the Chinese power system and that of Hughes's investigation of three Western electric systems, it can be seen that they evolved in a similar pattern but with their characteristics, and the phases 'overlapped and backtracked' (Thomas Parke Hughes, 1987, p. 56). The evolving process started from the invention and development of the system; in the Chinese case, technology transfer happened simultaneously in this phase. The advanced technology was brought by the scientists and engineers coming back from the West. Some of the equipment and infrastructures were by-products of the war. During the development phase, reverse salients emerged. Some were organisational or financial in nature, then the professional managers, financiers, and more often, in the Chinese context, the policymakers attacked the problems with inventive and innovative solutions. As the system matured, the system acquired style and momentum. In addition, the findings corroborate the ideas of Hughes, who suggested that power systems are artefacts congealed with cultures. Transnational influences deeply impacted the Chinese power system through the international connections with the West and the communist countries during the Cold War, which constructed and shaped the power system.

Chapter 3 then moves on to focus on the power industry's ongoing green transitions, aiming to investigate how and why the progressive change happened and the changing power relations in the transition process. The empirical investigation was conducted in the local electricity industry. The study has identified three stages of the local power system's green transition. Before 2013, a strong coal-fired power historical bloc was built on the solid societal commitment to coal-based economic growth. Efforts on enhancing energy efficiency and lowering emissions consolidate the coal-fired power bloc, as the electric utilities would advance the current energy system, which is composed of coal-fired power systems, rather than turn to the new energy system that renewables would dominate. 2013-2015 is the period when the coal-fired power hegemony was contested by the alienation of local government, who built a new alliance with local private solar PV manufacturers to save them from bankruptcy due to the precipitating international sanctions. The local authorities assist the private firms to seek the local market for the deployment of solar PV and low-speed wind power, which were not favoured by the state-owned generators. Starting from 2015, rapid uptake of renewable has happened in this region, mainly owing to the investment of state-owned generators. A new renewable energy bloc is forming as the SOEs and the citizenry are joining the alliance; however, it lacks the involvement of financiers. The results have indicated that the local authorities contribute to the introduction of renewables in the region driven by the economic incentives, and the SOEs triggered further green leapfrog driven by the market interests.

The evidence also suggests that the successful diffusion of green technology depends not only on physical and technological conditions but also on consent in government, business and civil society, which needs a clever strategy of disseminating complex socio-economic embeddedness of the new technology and good timing. A diverse group of actors, including private firms, local government authorities, and residents, coordinate their interests through common discursive articulation and economic arrangement. They have ingeniously avoided the confrontation with the existing regimes, carried out step-by-step experiments, and eventually succeeded in expanding renewables. Such a green coalition has developed considerable coherence and momentum and is thus able to continue its growth even in the absence of SOE. However, accelerating the transition requires bringing all the key stakeholders on board and requires they understand themselves as sharing interests and accept the full assimilation of renewables as common sense.

During the dynamic process of green transitions, SOEs are both delaying and propeller forces, private enterprises are the active actors, local government acts as both a legislator and educator, the role of the mass public changes from the consumers to prosumers, and the commercial banks keep holding back financing renewable energy projects. The (un)changing roles of prominent actors in the transition of the local power industry have the same motivation: seeking profits. Nevertheless, all evidence points out that business is the key to a successful transition.

By linking the periodisation of the power system's history in Chapter 2 with the periodisation of the local energy transition in Chapter 3, the following findings can be drawn. In the initial phase of the development of the Chinese power system and the local renewable energy sector, the elite scientist and engineers and entrepreneurs 'invented' (built) the power system and the renewable energy alliance. Also similarly, most of the elites in the renewable energy sector[39] were educated and trained in the West, like the pioneers who built the Chinese power system in the first half of the 20th century. Then the technology transfer occurred to adapt to local conditions, such as resource endowment, geographic environment, local legislation and electricity market, economic development level, and social norms. As the system grew, inadequate financial resources and institutional constraints were the reverse salients in the system's growth period from 1978 to 2002; in the same vein, insufficient sources of funds and the lack of a market mechanism for power distribution are the components that have fallen behind the others. The experience of 1978-2002 indicates that

[39] Interviewees workings in the local renewable energy firms all had a degree from a Western university. Gallagher (2014) also mentioned that the participants in her field study of Chinese solar PV manufacturers have a degree from a Western university; for example, a visited company's chief technology officer has a PhD degree from an Australian university.

the solution to such reverse salients brought a new and competing power system in 2002.

Chapter 4 focuses on the business, testing whether it pays to adopt green energies and the generators' perceptions of payoff. The statistical results have shown that it does pay to become green. The profitability of generators with a high share of renewable energy has grown faster than generators with a low proportion of renewables. The results also reveal that the profitability of generators having more than 40 per cent of renewables in their portfolio is less fluctuated and shows a clear upward trend.

Interviews indicate the differentiation between state-owned and private generators on the definition of payoff, and their perceptions of payoff have changed over time. SOEs changed their primary measurement of payoff from total generating capacity to growing profits, and such change resulted from changing standards of performance evaluation that the central government sets. Before 2013, the central government evaluated SOEs mainly by size; from 2013, and especially after 2015, the state has valued profitability more than the scale. SOEs are no longer mere state-run enterprises only receiving and implementing government plans; instead, they are now state-funded enterprises making money for the government and society. Such change leads to their investment portfolio change, as the renewable energy projects have shown higher profitability than the coal-fired power plants; thus, it also explains the rapid uptake of renewables after 2015 in the case in Chapter 2.

On the other hand, private firms have focused more on advancing technology and political legitimacy and prestige than pursuing pure profits since 2015. For private generators who step into the emerging green energy market, for instance, low-speed wind power, they now value technology innovation the most. Their focus is no longer on accommodating and catching up with a type of advanced technology but on continued learning by conducting their own experiments and taking chances to adapt and create new opportunities. While for those private firms that have already been in the renewable energy industry with relatively mature technology, like solar PV, their focus is on seeking political power and prestige to compete with the SOEs who newly enter the market and maintain their advantage in the SOE-dominant electricity industry.

6.2 Implications for the current transition

The results summarised above have six implications for the ongoing green energy transitions. First, linking the findings from the study of the Chinese power system's history to the evidence from the case study of the local energy transition, the results indicate that a green transition will not happen merely with adjustments to the existing power system but through a paradigm shift across economies, societies, and communities. It requires a rethinking of electricity markets in many aspects, like what had happened in the 1980s on financing mechanisms and in 2002 on comprehensive reconstructions of the institutions and needs concerted political and social efforts.

Second, the findings suggest that without real roots in civil society, the renewable energy historical bloc is likely to be weak, making the scale and pace of the transition barely achievable as expected. Thus, public involvement is of particular importance. How could the public get involved in an authoritarian country like China? The answer is certainly not by coercion but through consent. The evidence from the case study shows that the mass public's involvement is not conventional in China, neither taking the forms of mass movement and protest as we often see in other countries or through the voice and actions of non-governmental organisations. The citizens participate in the broader green transition through shared ownership in distributed power generation projects. They become shareholders of the project and see themselves as part of the state project. Once the public has recognised the green projects, continuous education is necessarily in need to change people's daily practices.

Third, education needs to be strengthened and reasserted. It is fundamental that we should focus on education aspects, educating all the shareholders and stakeholders: policymakers, users, financiers, and academics. The structural changes of the energy system have to be facilitated by deep educational reforms. The design and implementation of the green transition policies necessitate in-country human capital; thus, it requires equipping people, communities, and organisations with the skills and knowledge which can be delivered through education. The Chinese experience shows that education in rural areas is weak but crucial, which is common in poor regions globally. Rural electrification and the distributed renewable energy projects precisely offer a channel for the rural residents to receive education, and receiving such education would, in turn, enhance local support for the green transition and livelihoods conditions simultaneously. The Chinese experience also suggests that the importance of education and skills needs to translate into a central part of development policy in the government. The government has placed scientific education at the centre of its quest for growing, building modern universities, awarding scientific research and technological innovations, sending students abroad to study science and technology, just as in the Qing dynasty of the late 1890s, the Nationalist Government of 1930s, and Deng's era of the 1980s.

Fourth, the results provide insights into the decisive role of business actors, particularly the big generators, in accelerating the transition, highlighting the importance of cognitive revolution and openness and collaboration across the industry. Whilst governments set the framework, it is really business that delivers the transition. The transformative change of the whole energy system needs the synergistic interdependence of a group of industries with one or more infrastructural networks. It suggests that the business should, foremost, believe in the future of green power and view the uncertainties of green technology as opportunities to advance the whole system rather than threats. The generation magnates should not be constrained in the current technology pool but open to the new technology. Rather than waiting for public policies to facilitate or compel renewable energy deployment, firms would be better to have forward-thinking and see the potential of emergent technologies, such as hydrogen. Meanwhile, they could seek cooperation and collaborations with players in and outside the industry, such as Artificial Intelligence (AI) and 5G internet, which hold huge potential to improve the efficiency of the system and enhance the adaptation of the liberalised electricity market.

Fifth, the findings raised important issues about finance, which holds the key to accelerating the transition but is unwilling to open the door. Financial capital has the potential to bring about disruptive change as it has been done before in the 1980s when financing was the reverse salient, falling behind the growth of the power system, and a series of financial innovations had forcefully pushed the development forward. Likewise, finance is out of phase of other sectors in the current green transition. The existing financial products and financing structures are unfit to bankroll a transition. Drawing lessons from the 1980s' experience, it recommends that the regulatory authorities could incentivise experimentation and implication of innovative financing structures. Innovative green funds, green bonds, and green insurance schemes could be encouraged, so is the development of mechanisms to attract private capital. Meanwhile, we also need powerful legal signals of fossil fuel divestment to the world of finance. Once it is no longer profitable and legitimate to build coal-fired power plants, finance will reallocate the capital to the diffusion of green technologies projects.

Lastly, the results highlight the importance of the state, particularly the local state, in setting the framework for local energy transition, fostering innovation directly through funding research development and engineering, making the public investment in green infrastructure, coordinating the collaboration across industries, providing incentives for private green investment and offer educations for the mass public. Also, it is acknowledged that a new age of prosperity could be channelled in a green direction, and grasping this opportunity requires an active state that shifts the balance of power from coal-backed growth to green growth and changes the incentives from fossil fuels to green innovation. Radical policy changes are needed to tilt the playing field strongly towards green growth and innovation, and such policies can bring back growth and jobs and reduce inequality. The Chinese experience supports step-by-step experimentations, trial-and-error procedures, and pragmatic innovation, which take account of the conditions at each stage of the transition process and align the interests of the decentralised actors with those of the reformers in government.

6.3 Strengths of the study

This thesis presents a comprehensive and long-term examination of the evolution of the Chinese power system and its green efforts beyond a narrow focus on institutions and policy. The main strength of this research is the adoption of mixed methods, specifically reflecting in three aspects: data sources, research scope, and analysis process.

Firstly, the richness of data sources is the area where the advancements of the thesis are most visible. I have identified and collected a wide range of written and oral materials: industrial records, oral history, government documents published by central and local governments, reports and databases issued by international organisations, unpublished internal corporate documents, media interviews, in-depth interviews with various stakeholders, and informal discussions with participants in and observers of the industry on numerous occasions. To ensure data reliability, I have, whenever possible, attempted to validate data by cross-referencing data points across multiple sources and interview subjects. Quantitative databases were built on data collected in the field research.

Although the geographic scope is narrow and only includes two provinces in China, the scale of those provinces is comparable to and even much larger than a single country in other regions of the world along various dimensions: total installed capacity, installed coal-fired capacity, population and carbon dioxide emission. A single province's transition would significantly impact the national and global efforts of combating climate change. Also, the regions studied in my thesis are less developed and still industrialising; though the local experience is unique and cannot be easily replicated, their transition experience does offer lessons that developing countries might draw on. On the other hand, the temporal scope is comprehensive. The investigation started from the formation years of the system tracing back to the 1880s, which is excluded in earlier publications, and the quantitative database comprises corporate data over more than a decade. Interview subjects fall into broad categories: government officials across multilevel, managers and employees from electric firms, either state-owned, private-owned, or owned by township-village, financiers, and residents. Their voices have hardly been heard in earlier publications, and such exclusion is a major limitation of the existing literature.

The estimation approaches also advance the existing research. The historical approach used to analyse the qualitative data is a key strength of this thesis. The estimation procedure includes a critical examination of sources, data validation, and interpretation. The historical method provides the critical contextual link of the past to the present. It enhances the understanding of the present, given that contemporary issue is bound intrinsically with the socio-political milieu of the past. The longitudinal design and multilevel models applied for the quantitative analysis have three merits. First, the longitudinal design allows the separation of cross-sectional and longitudinal effects. Second, it provides a way to investigate heterogeneity across units at the overall level and across time. Third, the advantages of multilevel models lie in the flexibility to deal with unbalanced data structures and the capability to capture individual firms' growth and assess the change.

6.4 Limitations and recommendations for further research work

Irrespective of its many valuable insights, this thesis is subject to several limitations. First, the major limitation of this study is the lack of comparative analysis. The historical investigation of the power system is limited to China. However, comparisons with the evolution of power systems in other societies would provide a way to link causes to the range of outcomes; to better understand why a technology, institution, or a particular practice or behaviour developed in one society, not in another; and, to know whether one specific pathway or issue is unique to the society in question or common to many. Also, it would be interesting to compare the local or Chinese experiences of green transition to other regions where change has happened more rapidly or failed to launch. Thus, further work needs to be carried out to do a comparative analysis.

Second, the interview subjects in this thesis are limited to stakeholders within the industry. As actors outside the industry, such as Information and Communication Technology (ICT) companies and Electric Vehicle (EV) firms, become new game-changers in recent years, a further study could include the new game-changers to assess their potentially disruptive power and impacts on the green transition.

Third, the examination of the effects of being green is limited by the relatively small sample. More data would help us to establish a greater degree of accuracy on this matter. Further studies might repeat the experiments using a diverse sample of companies with various types of ownerships and green technologies.

Lastly, the research on local energy transition has shed light on the mechanisms underlying the transition. Therefore, additional subnational case studies in China would be useful, as would more focused studies in the rural regions. However, there exists a paucity of empirical case studies, indicating that conducting investigations at the local scale would be a fruitful area for further work.

Appendices

Appendix A Research design and procedures

	Procedures			Products
		Location		
Qualitative data collection	Pilot study	C-Province N-Province W-Province	Visited and interviewed generators: 2 in C-Province, 3 in W-province, and 2 in N-Province	Interview outline; Source identification
	First-round fieldwork	C-Province N-Province (provincial capital cities)	Visited C-Province and conducted interviews with 6 state-owned generators, 2 governmental officials from the provincial NDRC department, and 2 state-owned commercial banks Visited N-Province and conducted interviews with 5 state-owned generators, 1 manager from provincial grid firm, 1 state-owned commercial banks	Transcripts of interviews; Documents collection (see Table 1)
	Second-round fieldwork	2 cities in N-Province 3 cities and 3 villages in C-Province	Visited N-Province and conducted interviews with 4 managers from state-owned firms, 1 manager from municipal grid firm, 1 manager from a commercial bank Visited C-Province and conducted interviews with 10 managers from state-owned firms, 6 private-owned generators, 2 generation firms managed by township government (TVE), 1 manager from municipal grid firm, 4 municipal government officers, 3 managers from commercial banks, 9 residents	
	Third-round fieldwork	2 cities in C-province	Follow-up interviews: 6 telephone interviews, 2 face-to-face interviews; Attendance of industry workshops and conferences	
Qualitative analysis	Historical methods		Preliminary analysis; Source criticism: criticising and verifying the evidence; Thematic analysis	Themes; Identification of depended and independent variables
Quantitative data collection	Constructed two data sets: Corporation yearly financial and operating data at national level collected from China Electricity Council and Bloomberg, and Corporate financial and operating data provided by local generators; Selected data sample			A two-level model building on data of local generators
Quantitative analysis	Longitudinal multilevel modelling			Quantitative results

Appendix B Interview questions

<u>For participants from Power generation firms/plants</u>

1. Could you please introduce current power generation projects (type, time, scale, location, and overall financial performance)?
2. What kinds of major changes have the firm experienced during 2002 and 2017 (e.g. organisational structure, business structure, corporate strategy and etc.)?
3. What are the main corporate strategies relating to the green process for the past 15 years (2002-2017)? (Clean coal technology VS. renewable energy development)
4. Development of clean coal technologies:
    a. What kind of clean coal technology does the firm adopted? Why?
    b. What kinds of clean coal technology is the most efficient or suitable for the firm? Why?
5. Development of renewable energy development:
    a. What drives the changes? Please identify key incidents of the transition.
    b. What are the internal strengths and weaknesses of the corporate transitions?
    c. What are the external opportunities and threats faced by the firm during the process of transition? (from government, local environmental organisations and financial institutions)
6. What is the trade-off between the adoption of clean coal technologies and renewables? What is the optimal allocation?
7. Has the firm ever closed any thermal plant? Or is going to close any coal-fired plant? If yes, what kinds of thermal plant faced being shut down? How to deal with the unemployed staff?
8. What is the plan for the corporate development in future?
9. Technology innovation: why it started? internally? Or outsourced? If outsourced, who are the technology providers? Who will be in charge of training and maintenance?
10. For thermal plants:
    a. What kinds of coal are used? Where are the coal sourced? What is the cost of coal? What is the trend of the consumption and cost of the coal for the past 15 years?
    b. What are the main factors that influence the profitability of the firm?
    c. What kind of clean coal technology does the firm adopted? Why?
    d. What kind of clean coal technology is the most efficient or suitable one for the plant? Why?

For wind/solar plants:
a. What kind of technology does the firm adopt?
b. Is the technology self-developed or bought from other firms?
c. Why most of the PV solar projects and the plain wind farm projects are developed and operated by private power generation firms rather than state-owned firms?

<u>For participants from the local government</u>

1. What are the critical environmental and energy policies for the past 15 years?
2. What is the criterion of selecting clean projects? How does the government choose between different types of green projects?
3. How to balance the local economic development and environmental protection?
4. What is the government attitude towards the current and future development of local thermal power generation firms and renewable energy power firms?
5. Did the government experience any dilemma in the process of promoting the energy transformation of the local power industry?

<u>For participants from the grid firm</u>

1. What are the determinants and consequences of corporate decisions among grid firms to purchase renewable and non-renewable sourced electricity?
2. What are the main drivers and constraints of the local development of renewable energy?

3. How does the grid firm coordinate other participants (e.g. generators and governments) in the electric industry?

<u>For participants from local commercial banks</u>

1. What is the loan policy towards the traditional energy project and renewable energy project?
2. What kinds of energy projects does the bank prefer to finance? Why?
3. What is your opinion of the local development of renewables?
4. What are the risks and benefits of financing renewable energy projects?

Why most of the PV solar projects and the plain wind farm projects are developed and operated by private power generation firms rather than state-owned firms?

Appendix C Chronology of People's Republic of China's electricity industry

		Institutional Structure	Key Policies			Pricing	Critical Events
			Electricity/Energy	Environment	Finance		
1949		Ministry of Fuel Industry; Ministry of Water Resources (MWR)					
1952		State Development and Planning Commission (SDPC)					1950-1953 Korean War
1953	1st FYP						
1955		Ministry of Electric Power Industry (MEPI)					
1958	2nd FYP	~~MWR & MEPI~~ Ministry of Power Industry					
1960s, sever relations with the Soviet Union; 1958-1960 The Great Leap Forward; 1966-1976 Cultural Revolution							
1978	Deng Xiaoping, 'Economic Reform and Opening Door'						
1979				Environmental Protection Law			Establishment of Sino-Japanese diplomatic relations (in 1972); Establishment of Sino-U.S. diplomatic relations
1985			Encouraging fund-raising for power generation (StateCouncil, 1985)			'Power purchase agreement'	
1987			Levying power construction funds (StateCouncil, 1987)				
1988			Reform plan of the power sector (StateCouncil, 1988)			'Fair dispatch rule'	
1989				Revised Environmental Protection Law			
1996	9th FYP		Electricity Law				
1997		**State Power Corporation (SPC)**	Energy Conservation Law				Kyoto Protocol; Asia financial crisis
1998		~~Ministry of Power Industry~~ State Economic and Trade Commission (SETC) and (SDPC)	Issues regarding power sector reform (Document No. 146) (StateCouncil, 1998)			'operating period power price'	
2000			Issues regarding power sector reform				

			(Document No. 69) (StateCouncil, 2000)				
2001	10th FYP		FYP for Electricity Power Industry (SETC, 2001)				California crisis; Join WTO
2002	16th Congress Party	~~SPC~~	**Reform Plan of Electric Power Industry** (StateCouncil, 2002)				Economic stimulus package
2003		**State Electricity Regulatory Commission (SERC);** National Development and Reform Commission (NDRC) (previous SDPC); State-owned Asset Supervision and Administration Commission (SASAC)	Electricity price reform plan (StateCouncil, 2003) Dispatching rules (SERC, 2003a, 2003b)			Benchmark feed-in tariff mechanism	
2004						Benchmark feed-in tariff for coal-fired generators	
2005			Renewable Energy Law			Additional charges for desulphurisation	
2006	11th FYP						
2007			11th FYP for Energy Development (NDRC, 2007a); Shutting down small power units (NDRC & NEA, 2007)	Climate change white book (NDRC, 2007b)	Green finance and credit risks (MEP, CBRC, & PBOC, 2007)		
2008							Global Financial crisis; domestic natural disaster
2009			Amendments to Renewable Energy Law			Four category feed-in tariff for wind	
2010			Energy efficiency of SOEs (SASAC, 2010)				
2011	12th FYP		FYP for energy development (NDRC, 2013) FYP for clean coal technology (MOST, 2012)			Additional charges for denitrification	EU&US embargos on Chinese solar panel manufacturers

2012	18th Congress Party- Xi Jinping				Renewable Energy Fund (MOF, NDRC, & NEA, 2011, 2012)		SASAC cash injection of Big Five thermal generators; Nation-wide air pollution outbroke
2013		~~SERC,~~ **National Energy Administration (NEA)** (under NDRC);	Action plan on fully rural electrification (NEA, 2013)	Air Pollution Prevention and Control Action Plan (2013-2018) (StateCouncil, 2013)		Four category feed-in tariff for solar PV; Additional charges for dust removal	Beautiful China Initiative; anti-corruption
2014			Retrofitting of coal-fired power plants (2014-2016) (NDRC et al., 2014a)；Energy Development Strategy Action Plan (2014-2020) (StateCouncil, 2014a);	National Plan on Climate Change (2014-2020) (NDRC, 2014)			Joint US-China Climate Statement
2015			**Further reform of the electric power industry (Document No.9)** (StateCouncil, 2015a); Operational adjustments for clean energy generation (NDRC & NEA, 2015a); Project approval release (NDRC & NEA, 2015b)	Revised Environmental Protection Law; Ultra-low emission and energy conservation for coal-fired power plants (MEP, NDRC, & NEA, 2015)		lower feed-in tariff for wind and solar PV electricity	Accomplishment of rural electrification ; Paris Agreement
2016	13th FYP		FYP for Energy Development (NDRC & NEA, 2016d); FYP for the Electricity Power Industry (NDRC & NEA, 2016b); Solar PV poverty alleviation (NDRC & NEA, 2016c); Full acquisition of renewable generation (NDRC, 2016)		Establishing the Green Financial System(PBOC, 2016a); Opinions on Financial Support for Poverty Alleviation (PBOC, 2016b)		
2018			Renewable quotas allocation system proposal (NDRC & NEA, 2018)	Three-Year Action Plan on Blue Sky War (StateCouncil, 2018)			

Appendix D Chinese Communist projects of the electric power industry receiving Soviet equipment and technical aid

Project	Location	Remarks
Transmission line project	Northeast	Connecting An-shan, Mukden, Fu-shun, Fou-hsin, and Pen-ch'i.
Power plant expansion	Fou-hsin	Two separate stages of power plant expansion, probably indicating two separate projects.
Power plant expansion	Dairen	
Power plant expansion	Fu-shun	Two separate stages of power palnt expansion, probably indicating two separate projects.
Hydroelectric power station	Ta-feng-man Dam (Kirin)	May have been broken into 2 or 3 separate projects.
Power plant	Fu-la-erh-chi (near Ch'i-ch'i-ha-erh)	Planned major power plant (under construction).
Thermal electric power station	T'ai-yuan	
Power plant	Pao-t'ou	Plant barely started now.
Power plant No.2	Sian	In partial operation, August 1953.
Power station	Cheng hsien	Scheduled to begin 'partial operation in October 1953.
New thermal power plant	Urumchi	Scheduled to begin operation in October 1953; output to equal 140 percent of present generation in province.
Power plant No. 507	Chungking	Scheduled to begin operation in 1953.
Two or three small power plants	Yunnan	Part of development of tin mines.
Hydroelectric power plant	Shih-lung-pa (near K'un-ming)	Barely started now.

Source: Reproduced from Table 13: Chinese Communist projects of the ferrous metals electric power industry receiving Soviet equipment and technical aid in CIA (1955)'s report on Soviet Economic Assistance to the Sino-Soviet Bloc Country, p68-69.

Appendix E Overview of the interview data collection

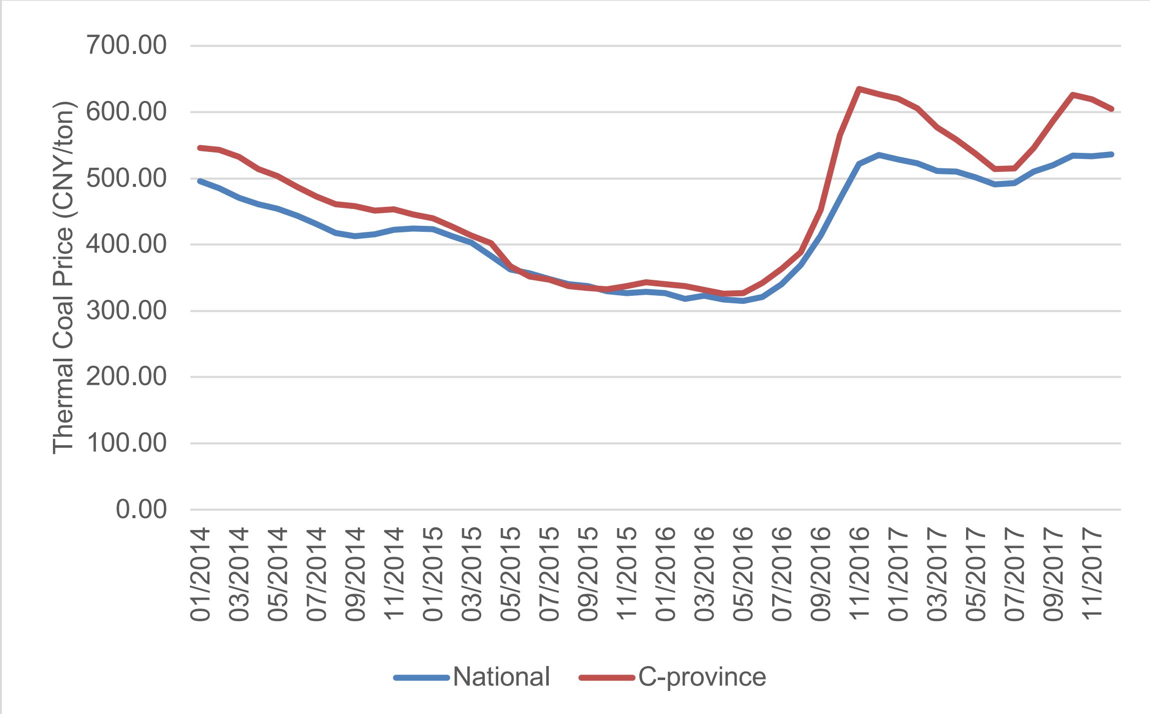
	First round	Second round		Third round
	Provincial level	City-level	Village-level	
Generator	6 state-owned corporations (Code: Csp)	10 state-owned generators (Code: Cs) 6 private-owned firms (Code: Cp)	2 TVEs (Code: Ct)	Cs7 (telephone) Ct1 (telephone)
Government	2 (Code: Gp)	4 (Code: G)		G2 (face-to-face)
Grid firm		2 (Code: R)		
Commercial bank	2 (Code: Bp)	3 (Code: B)		Bp1 (face-to-face and telephone) B2 (telephone)
Local resident		4 (Code: res)	5 (Code: res)	res3 and res4 (telephone)

Appendix F Energy and power production in C-province

	Coal-fired Power			Wind Power		Solar PV			
	Total Installed Capacity (MW)	Total Power Generation (100 million kWh)	Utilization hours	Total Installed Capacity (MW)	Total Power Generation (100 million kWh)	Total Installed Capacity (MW)	Utility-scale solar PV (MW)	Distributed rooftop Solar PV (MW)	Total Power Generation (100 million kWh)
2008	42507.4	1754.92	4128.50	48.75					
2009	42937.9	1952.61	4547.52	48.75					
2010	41353.8*	2092.09	5059.00	121					
2011	48845.9	2467.24	5051.07	300					
2012	51882.4	2422.41	4669.04	492		64	0	64	
2013	55492.7*	2741.34	4940.00	642.12	6	69	3	66	
2014	56855	2613.12	4596.11	962.82	6.76	230	70	160	
2015	61627.9	2481.30	4026.26	1663	12	410	140	270	
2016	63807.4	2679.38	4199.17	2362	18	2840	2480	360	3.66
2017	66012.9	2349.98	3559.88	3610	30	7040	5300	1740	12.81
2018	67570.9	2657.62	3933.08	5956	56.89	9910	6000	3910	83.77
Source	Provincial NEA	NEA	Provincial NEA	Provincial NEA & Chinese Wind Energy Association	NEA	Provincial NEA	Provincial NEA	Provincial NEA	NEA

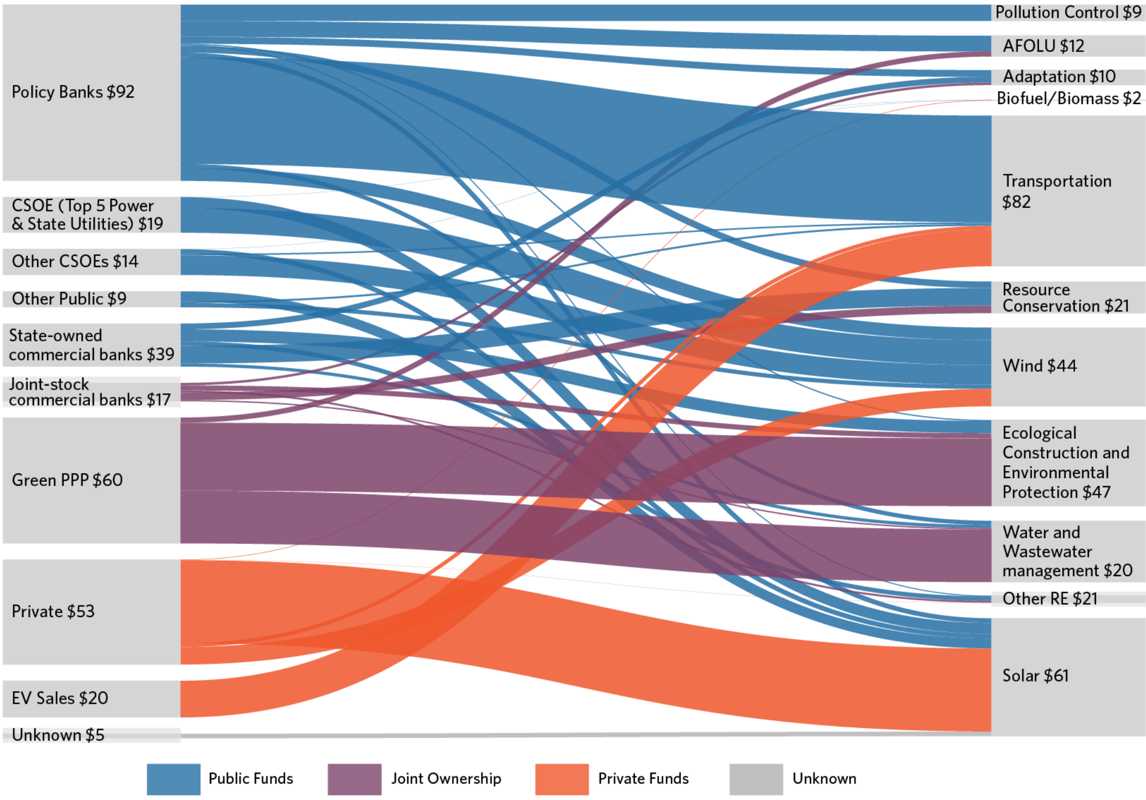
*Self-calculated based on the utilization hours of coal-fired power sector released by the provincial NEA and total power generation (kWh) released by NEA

Appendix G China Thermal Coal Index from 2014 to 2017



Source: Price Monitoring Centre of National Development and Reform Commission of China

Appendix H China's green finance, from financing source to sector allocation



Source: Climate Policy Initiative (CPI, 2021)

Appendix I Empirical studies on the relationship between corporate financial performance and corporate social/environmental performance

Author(s)	Sample	Financial variables	Environmental variables	Results
D. L. Levy (1995)	80 transnational U.S.-based corporations, between 1987-1989 and 1991-1992	Return on asset, return on sales, current ratio	Changes in Toxic Chemical Release Inventory (TRI) emissions	Reducing emissions does not yield significant financial benefits
S. L. Hart and Ahuja (1996)	127 mining and manufacturing firms in S&P 500, 1989-1989	Return on sales, return on assets, return on equity (with time lag: t+1, t+2, t+3)	Emission reductions (derived from IRRC's 1993 Corporate Environmental Profile)	It pays to be green: emission reductions significantly enhance ROS and ROA for t+1, t+2 and t+3, peaking in t+2; and enhance ROE with a two-year lag.
Klassen and McLaughlin (1996)	96 firms publicly traded on New York Stock Exchange (NYSE) or American Stock Exchange (AMEX), 1985-1991	Stock returns	Environmental events: environmental awards and crisis	Significant positive abnormal stock returns on the announcement of positive environmental events; significant negative returns for the environmental crisis.
Nehrt (1996)	50 chemical bleached paper pulp manufacturers in Brazil, Canada, Finland, France, Portugal, Spain, Sweden, and the U.S., 1983-1991	Net income growth (measure by the percentage growth in real local currency net income from the mean for 1983-1985 to the mean for 1989-1991)	Timing of investments (measured by the number of years the firms invested in pollution-reducing technologies); Intensity of investments (measured by the percentage of firm's total capacity that is capable of producing less-pollutant pulps)	Pollution reduction investments have significantly positive influence on financial performance; early-movers gain higher profit growth than later investors; the effect of environmental regulation is not significant.
White (1996)	97 firms listed on NYSE or AMEX, 1989-1992	Jensen's alpha	Environmental reputation indices published by the Council of Economic Priorities (three portfolios)	It pays to be green: the 'green' portfolio provided a significantly positive Jensen's alpha, while the 'brown' and 'oatmeal' portfolios failed to outperform the market.
M. A. Cohen, Fenn, and Konar (1997)	Firms in S&P 500, 1987-1989	Return on assets, return on equity; total risk-adjusted return on shareholders	Self-constructed indicators based nine measures from government documents and corporate 10-K filings (two portfolios consisting of 'High polluters' and 'low polluters')	No significant relation between environmental practices and financial performance
Cordeiro and Sarkis (1997)	523 U.S. firms, 1992	1-and 5-year earnings-per-share	Environmental proactivism using Toxic	Environmental proactivism negatively

		performance forecasts)	Chemical Release Inventory (TRI) data	affected *short-term* financial performances
Russo and Fouts (1997)	243 U.S. firms, 1991 to 1992	Return on assets	Environmental ratings by the Franklin Research and Development Corporation	It pays to be green: a high level of environmental performance is associated with enhanced profitability
Yamashita et al. (1999)	30 American manufacturing companies, May 27 1993 to August 13 1993	Risk-adjusted stock returns	Environmental conscientiousness score published in *Fortune* Magazine	Environmental-friendly practices have positive, but not significant, impacts on financial performance
Dowell et al. (2000)	89 U.S. based manufacturing and mining multinational enterprises in S&P500, 1994-1997	Tobin's q	Corporate environmental standards (separated by firms adhering to local environmental standards, U.S. environmental standards, and internal standards that exceed any national standard)	Adopting stringent environmental standards enhance firm value.
K. M. Gilley et al. (2000)	Firms in 16 U.S. industries subject to 71 announcements of corporate environmental initiatives published in the *Wall Street Journal*, 1983-1996	Cumulative average abnormal returns	Corporate environmental initiatives (39 process-driven, 32 product-driven)	No overall effect of announced environmental initiatives on stock returns; investors react more positively to product-driven environmental initiatives relative to process-driven ones.
King and Lenox (2001)	652 U.S. manufacturing firms, 1987-1996	Tobin's q	Total emission, relative emission, industry emission (based on TRI data)	No evidence shows firms that operate in cleaner industries have higher financial performance, or firms that move to cleaner industries improve their financial performance.
Wagner et al. (2002)	European paper manufacturing industry, 1995-1997	Return on equity, return on capital employed, return on sales	self-calculated environmental index based on SO_2 emissions, NO_x emissions and COD emissions	Negative relationship between environmental and economic performance
Clarkson, Li, and Richardson (2004)	29 U.S. pulp and paper firms, 1989-2000	Market value of equity	(non-)Environmental capital expenditure (high-polluting firms vs. low-polluting firms)	Incremental economic benefits associated with environmental capital expenditure investment by low-polluting firms but not high-polluting firms.
Filbeck and Gorman (2004)	24 public electric utilities in IRRC/S&P500, 1996-1998	Market value of equity	Investor Responsibility Research Centre (IRRC) Compliance Index (two	No relationship between environmental performance and financial performance.

			portfolios: 'less compliant' and 'more compliant')	A negative relationship between financial returns and a more pro-active measure of environmental performance. No direct relationship between regulatory climate and environmental performance.
Derwall et al. (2005)	180 U.S. firms, 1995-2003	CAPM	Eco-efficiency ratings by Innovest Strategic Value Advisors (two portfolios: high-ranked and low-ranked eco-efficiency portfolios)	Environment-friendly firms have higher stock return. Social responsible investment generate substantially incremental benefits.
Karpoff et al. (2005)	478 environmental violation events, 1980-2000	Abnormal stock returns	Environmental violations reported in the *Wall Street Journal*	Firms investigated or charged with violating environmental rules experience statistically significant and economically meaningful decreases in common share values. Environmental violations do not hurt firms' reputation; only the initial press report of a violation causes a significant stock price reaction.
Aragón-Correa, Hurtado-Torres, Sharma, and García-Morales (2008)	108 SMEs in the automotive repair sector in Southern Spain (interviews)	Subjective perceptions of managers, objective data	Environmental strategies	SMEs can adopt proactive environmental practices and that these practices can lead to superior financial performance. A positive relationship between the most proactive environmental practices and firm performance exists for both the sampled SMEs and larger firms.
Hull and Rothenberg (2008)	69 U.S. firms, 1998-2001	Return on assets	Self-constructed index of Corporate Social Responsibility index based on Kinder Lydenberg Domini (KLD) ratings	Corporate social performance positively affects financial performance. Innovation positively impacts financial performance. Corporate social performance most

				strongly affects performance in low-innovation firms and in industries with little differentiation
Godfrey et al. (2009)	160 firms, 1991-2002	Cumulative abnormal stock returns	Corporate social responsibility ratings (178 negative legal/regulatory actions against firms in Socrates database from 1993 to 2003)	Corporate social responsibility activities, particularly investment aimed at secondary stakeholders or society, could create value (an 'insurance-like' benefit) for shareholders in the face of certain types of negative events.
Sueyoshi and Goto (2009)	167 U.S. electric utility firms, 1989-2001	Return on assets	Environmental protection facilities % (long-term efforts); Environmental protection cost % (short-term effort)	The environmental expenditure under the U.S. Clean Air Act has had a negative impact from 1989 to 2002, especially after 1995. There is a possibility that facility investment for environmental protection may positively impact financial performances in the long-term horizon but could not be statistically confirmed.
Jacobs et al. (2010)	780 environmental initiative or awards announcement spanning 340 firms, 2004-2006	Abnormal stock returns	Announcements of Corporate Environmental Initiatives, Environmental Awards and Certifications	Market is selective in reacting to announcements of environmental performance with certain types of announcements even valued negatively.
Wagner (2010)	358 U.S. firms, 1992-2003	Tobin's q	Corporate sustainability performance index based on Kinder Lydenberg Domini (KLD) data	There is a positive association of corporate sustainability performance with economic performance. Innovation activities do not *per se* improve the effect of corporate sustainability. Environmental performance has a direct effect on economic performance, social performance only has a fully moderated effect on economic performance.
Busch and Hoffmann (2011)	174 largest companies by market cap within	Return on assets,	Carbon intensity,	When using carbon emissions as an outcome-based measurement, corporate environmental

	the Dow Jones Global Index	Return on equity, Tobin's q	Carbon management strategies	performance pays off. When using carbon management as a process-based measurement, corporate environmental performance negatively associates with corporate financial performance.
Clarkson et al. (2011)	242 U.S. firms in pulp and paper, chemical, oil and gas, metal and mining industries, 1990-2003	Return on assets, Operating cash flow, Total debt to asset ratio	Pollution propensity (calculated based on TRI data)	Positive relationship between financial performance and environmental performance. Only firms with sufficient financial resources and management capabilities can pursue a proactive environmental strategy.
Fisher-Vanden and Thorburn (2011)	117 announcements, 1993-2008	Cumulative abnormal returns	Announcement of joining Climate Leader or Ceres programme, Announcement of a GHG reduction goal	Voluntary corporate environmental initiatives have negative impacts on firm value. Corporate commitments to reduce greenhouse gas emissions conflicts with firm value maximisation.
Guenster, Bauer, Derwall, and Koedijk (2011)	154 U.S. firms, 1997-2004	Tobin's q, Return on assets	Eco-efficiency scores developed by Innovest	Eco-efficiency relates positively to operating performance and market value.
Iwata and Okada (2011)	268 Japanese manufacturing firms, 2004-2008	Return on assets, Return on equity, Return on investment, Return on sales, Return on invested capital, Tobin's q	Waste and greenhouse gas emissions (from the Corporate Social Responsibility Database released by Toyo Keizai)	Waste emissions do not generally have significant effects on financial performance. Greenhouse gas reduction leads to an increase in financial performance in the whole sample and clean industries but no effects in dirty industries. As the firm growth rate increases, the partial effects of waste emissions on financial performance decrease, whereas the partial effects of greenhouse gas emissions on financial performance increase.

Ameer and Othman (2012)	Top 100 sustainable global companies, 2006-2010	Sales growth, Return on assets, Profit before tax, Cash flow from operating activities	Self-constructed sustainable practice indices	Companies with superior sustainability practices have superior financial performance. Higher financial performance of sustainable companies has increased and been sustained over the sample.
Horváthová (2012)	1176 firm year observations in Czech Republic, 2004-2008	Return on assets, Return on equity	Normalised emission amount, EMAS and ISO4000 certifications	The effect of environmental performance on financial performance is negative for 1 year lag, it becomes positive for 2 years lag. Porter Hypothesis holds in the long run.
Kroes et al. (2012)	36 U.S. public utility firms operating coal-fired generating units, 2004-2006	Tobin's q	SO_2 emission	Pollution prevention and pollution control reduced market performance over at least a three-year period
Lioui and Sharma (2012)	17465 firm year observations, 1991-2007	Return on assets, Tobin's q	Environmental strength, Environmental concerns (based on environmental corporate social responsibility ratings from KLD)	Negative relationship between financial performance and environmental performance. CSR activity fosters R&D efforts of firms which generates additional value (indirect effect).
Fujii et al. (2013)	Japanese manufacturing firms (758 observations on CO_2 emissions, 2006-2008; 2498 observations on aggregated toxic chemical substances, 2001-2008)	Return on assets, Return on sales, Capital turnover	CO_2 emissions, Aggregate toxic risk (from Ministry of Environment, Japan)	There is a significant inverted U-shaped relationship between ROA and environmental performance calculated by aggregated toxic risk. A significant positive relationship between financial performance and environmental performance based on CO_2 emissions.
Oberndorfer, Schmidt, Wagner, and Ziegler (2013)	German firms, 1999-2002	Cumulative abnormal returns	Dow Jones STOXX sustainability index, Dow Jones sustainability World index	Stock markets may penalize the inclusion of a firm in the sustainability stock index.

Ghisetti and Rennings (2014)	1063 German firm-observations in two waves of surveys in 2009 and 2011	Return on sales	Energy and resource efficiency innovations, Externality reducing	A reduction in the use of energy or materials per unit of output positively affect firms' competitiveness. Externality reducing hamper firms' competitiveness.
Pätäri et al. (2014)	14 energy-sector companies, 1991-2009	Return on assets, Market capitalisation	CSR strengthen, CSR concerns (based on ratings by KLD)	CSR concerns Granger-cause both profitability and market value. CSR strengths only Granger-cause market value. The effects of changes in CSR strengths on market value appear after shorter lags (starting with one year) than the effects of changes in concerns (starting with a four-year lag).
Qi et al. (2014)	39 industrial sectors in China, 1990-2010	Return on assets	SO_2 emission intensity	Improving corporate or industrial-level environmental performance significantly influences financial performance. Slack resources play a significant role on the link.
K. Chang (2015)	142 Chinese heavy industrial firms, 2008-2012	Tobin's q	Environmental performance scores, Environmental propensity disclosure (by information disclosure)	The quality of environmental performance is low. Corporate environmental performance has a negative effect on financial performance.
Muhammad, Scrimgeour, Reddy, and Abidin (2015)	76 Australian firms, 2001-2010	Return on assets, Tobin's q	Toxicity weighting scores, Environmental awards, Environmental management team, Environmental supply team	There is a positive relationship between environmental and financial performance during the pre-crisis period of 2001-2007; no relationship during the crisis period of 2008-2010.
Chopra and Wu (2016)	454 firms in the global computer and electronics industry, 2000-2011	Return on assets, Return on sales	Eco-collaboration,	Eco-activities have a positive effect on operating income and operating margin about three years after the announcement of eco-

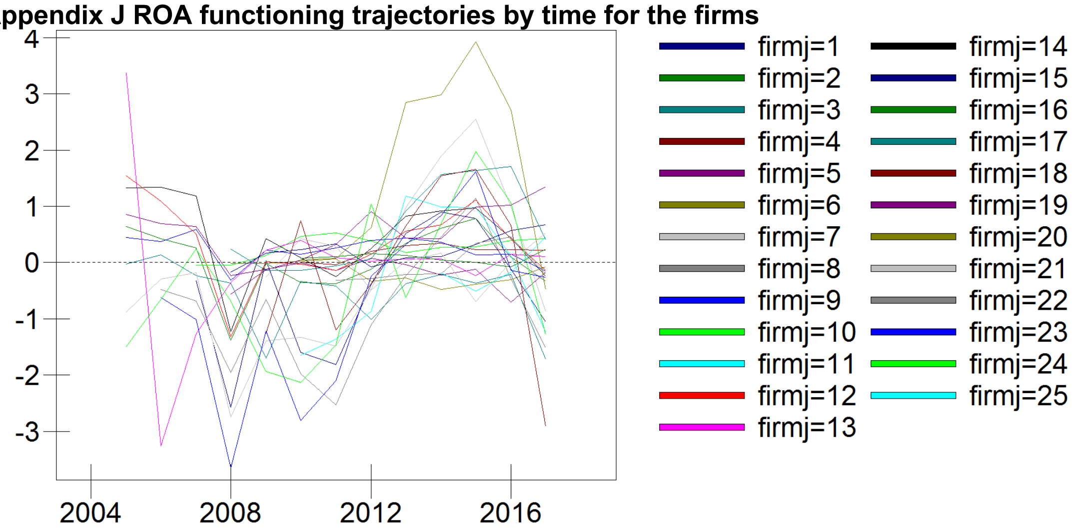
			Eco-certification (from the Thomson Reuters ASSET4 database)	activities implementation.
Shin et al. (2016)	60 top renewable energy-user firms in U.S., 2007-2013	Return on investment, Tobin's q, Operating margin	Renewable energy activities	Top renewable-energy user firms consistently generated superior financial performance compared to their industry competitors.
X. Zhao and Sun (2016)	Pollution-intensive corporations in China, 2007-2012	Return on assets	Self-calculated Environmental regulation index	Environmental regulation has significant weak positive effects on corporation's innovation. Corporation innovation has a significant strong positive effect on corporation competitiveness. Environmental regulation has insignificant negative effects on corporation competitiveness. East and middle regions have weak porter hypothesis phenomenon while that of the west region is not significant.
Ait Sidhoum and Serra (2017)	19 U.S. electric utility holding firms, 2005-2012		CSR indicators from ASSET4 database for four pillars: economic, environmental, social, and corporate governance performances	Economic performance of utilities is compatible with environmental, social, and governance performance.
L. W. Fan, Pan, Liu, and Zhou (2017)	17 energy-intensive firms in China, 2000-2014	Return on assets, Return on equity, Return on investment, Return on invested capital, Return on sales, Tobin's q	Energy efficiency: energy intensity – the ratio of total energy use (in the unit of tonnes of standard coal) to operating revenue (in the unit of 10,000 yuan)	Energy efficiency is positively related to ROE, ROA, ROI, ROS, but no significant relationship with Tobin's q. Firm growth helps to enhance the positive relationship between energy intensity and financial performance.
Gonenc and Scholtens (2017)	23307 fossil fuel firms in 51	Tobin's Q,	Environmental scores (from Thomson Reuters' ASSET4 ESG database)	Environmental outperformance has no impact on financial performance for

	countries, 2002-2013	Excess stock returns, Return on equity, Business risk, Beta		chemical firms, reduces returns and risks for coal companies, has a mixed impact on return on oil and gas, and reduces financial risks for oil and gas firms. Financial outperformance reduces environmental performance in all fossil fuel (sub)industries investigated.
Ibikunle and Steffen (2017)	1414 European funds, 1991-2014	Risk-adjusted returns	Three portfolios: 175 European green mutual funds, 259 fossil energy funds, 976 conventional mutual funds	Green mutual funds significantly underperform relative to conventional funds. No significant risk-adjusted performance differences between green and black mutual funds during the same period. Green funds are beginning to significantly outperform black funds, especially over the 2012–2014 investment window.
Liang and Liu (2017)	1310 CSR reports of Chinese industrial firms, 2010-2015	Net profit rate	Level of corporate environmental performance (based on content analysis of CSR reports), Level of environmental management capability	The level of environmental performance and environmental management capability of Chinese industrial firms are generally low. Concerning on environment does not significantly improve economic performance as a whole. The moderating effect of environmental management capability improving the economic value of environmental performance is limited at present.
Martí-Ballester (2017)	574 multinational companies from 36 countries, 2008-2013	Return on assets, Tobin's q	Consumption of renewable energy, Energy efficiency, energy efficiency management (from ASSET4 database)	Adoption of sustainable energy systems allows firms to improve their short-term FP while not leading them to reduce their FP in the long term. Improvements in energy efficiency and the use of renewable energy

				sources do not significantly affect corporate financial performance.
Ruggiero and Lehkonen (2017)	66 electricity utilities from 26 countries, 2005-2014	Return on assets, Return on equity, Tobin's' q	Volume of renewable energy produced yearly	Negative correlation at the firm level between RE increase and short-term as well as long-term financial performance. An increase in RE penetration Granger-causes a reduction of long-term performance. Firms' carbon intensity moderates the relationship.
Seng and Vithessonthi (2017)	83 publicly listed non-financial firms in Netherlands, 2001-2014	Return on assets, Return on equity, Return on sales, Stock returns	Renewable energy intensity	Firms with higher degrees of environmental efforts have better firm performance, measured as ROA; poor firm performance, measured as ROS; no association measured as ROE or stock returns.
Song, Zhao, and Zeng (2017)	2824 A-shares listed companies in China, 2007-2011	Return on equity, Earnings per share	Environmental management index (calculated by scoring four activities: 'Governance the contaminated environment', 'Recycle environmentally hazardous material', 'Produce environmentally friendly products', 'Adopt other methods to control pollution')	Environmental management is significantly positively related to financial performance in the following year. Environmental management is not significantly related to improved financial performance in the current year. Two methods of environmental protection, "recycled harmful substances to the environment (Rec)" and "other methods to control pollution (Other)," positively impact future financial performance, but no impact on the financial performance of the current year.
Jiang, Xue, and Xue (2018)	44 Chinese energy-related firms distributed in five different industries (2	Return on assets	Self-constructed proactive corporate environmental responsibility index	Proactive corporate environmental responsibility has a positive effect on

	privately-owned firms), 2009-2014		(based on the Golden Bee CSR Reporting Rating database)	corporate financial performance. Private ownership has stronger promotion on the relationship between proactive corporate environmental responsibility and corporate financial performance.
Gupta (2018)	23301 firms from 43 countries, 2002-2012	Implied cost of equity	Self-calculated firm's environmental performance ESI (based on ASSET4)	An improvement in environmental practices leads to reduction of the implied cost of equity; the results are stronger in countries where country-level governance is weak.
Z. Wang et al. (2018)	15418 firm-year observations in China, 2008-2014	Tobin's q, Market-to-book ratio	CSR score from RKS rating agency, Bloomberg ESG scores	CSR performance is more negatively related to CFP for politically embedded firms than for firms without political embeddedness. Politically embedded firms, and particularly firms that are centrally politically embedded, are more likely to issue CSR reports than firms without political embeddedness. Politically embedded firms have higher CSR performance.

Appendix J ROA functioning trajectories by time for the firms



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