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# **Actor interactions and niche acceleration**

## **Explaining China's rapid wind and solar development**

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Submitted in part fulfilment of the requirements for the degree of Doctor of  
Philosophy in Science and Technology Policy Studies

Science Policy Research Unit

University of Sussex

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## DECLARATION

I hereby declare that this thesis has not been and will not be submitted in whole or in part to another University for the award of any other degree.

Signature:.....Kejia Yang.....

UNIVERSITY OF SUSSEX

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DOCTOR OF PHILOSOPHY IN SCIENCE AND TECHNOLOGY POLICY STUDIES

ACTOR INTERACTIONS AND NICHE ACCELERATION: EXPLAINING CHINA'S RAPID WIND AND  
SOLAR DEVELOPMENT

## SUMMARY

Since the beginning of the 21<sup>st</sup> century, due to climate change and other environmental concerns, the energy sector has been shifting rapidly towards renewable energy. Green and low carbon have emerged as new priorities shaping the sector's future development. This development has not only been put into motion by a whole set of new actors, but it has also involved existing incumbents. While interaction between these two groups of actors has recently received more attention in the sustainability transitions literature, overcoming an original bias towards new entrants, the inner workings of this interaction are yet to be explored. This thesis addresses this research gap. The main question it asks is how the interaction between new entrants (called niche actors, following the sustainability transitions literature) and incumbents (called regime actors) shapes the rapid expansion of renewable energy development (called niche acceleration).

This research examines the case study of China. The country not only has the world largest energy sector, with entrenched coal power, but it also experienced rapid growth in renewable energy, in particular wind and solar power. China can therefore serve as an exemplary (or revealing) case study to investigate how the new entrants interact with incumbent actors in shaping the low-carbon transition dynamics in its electricity socio-technical system. The thesis focuses on wind and solar power development from 2000 to 2017<sup>1</sup> at the national level and within two provinces, Inner Mongolia and Jiangsu, where divergent developments were observed. Inner Mongolia's rapid wind and solar power development fits into the existing centralised power system. In comparison, Jiangsu province's relatively moderate wind power development combined with rapid solar photovoltaics (PV) development are transforming the existing centralised power system towards a more distributed one.

This thesis offers both conceptual and methodological contributions presented in three core chapters (chapters 3–5), which have been either published or submitted as journal articles. Chapter 3 develops a novel conceptual framework to study how the alignment dynamics

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<sup>1</sup> The focal analysis stages of cases in the three core chapters are slightly different. Chapters 3 and 4 examine the historical development from 2000 to 2017. Chapter 5 covers the period from 2000 to 2018 because the study and analysis were conducted at the later stage of four years' expanded PhD project.

between niche actors and regime actors unfold and shape niche acceleration. Moreover, it offers a novel quasi-quantitative methodology to map their alignment dynamics. Chapter 4 contributes a new understanding of how niche actors interact with regime actors to shape niche shielding dynamics that hold off selection pressures from the socio-technical regime. Chapter 5 proposes a new conceptual framework to study how niche actors interact with regime actors to shape the directions of niche development. Chapters 4 and 5 add a spatial dimension to the conceptual discussions.

The synthesis of the three core chapters' research findings suggests three key conclusions:

- 1) Strong alignment between niche and regime actors' expectations is necessary for niche acceleration (rapid niche development) in China at both the national and the provincial level. Despite China's specific governance characteristics, I suggest that this may also apply to other contexts.
- 2) The alignment between niche and regime actors can take different forms across multiple regime dimensions and across multiple scales. These forms are crucially important for understanding the building up and phasing out of effective shielding niche strategies.
- 3) The specific nature of niche and regime actors' alignment influences the direction of niche development, towards either a centralised or a decentralised energy system. The nature of their alignment is characterised by three aspects (i) the portfolio of institutional work that niche and regime actors enact in terms of working on creating niches, maintaining the existing regime and actively disrupting the regime; (ii) whether niche actors play a leading role in shaping institutional change working with regime actors, or regime actors play a leading role and ignore the disruptive institutional work of niche actors; and (iii) how they mobilise institutional conditions across multiple scales.

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## Preface

The thesis is motivated by the desire to understand how different actors interact to shape wind and solar power development in China. Over the last two decades, these two renewable energy technologies have diffused rapidly in China. This is remarkable considering the huge system lock-in in a coal power-fuelled energy system and the existence of many structural barriers for renewable energy diffusion. From this perspective it is astonishing to see China moving rapidly towards wind and solar power. It leads to several questions: How can we understand this rapid development of wind and solar energy in China over the last two decades? Is China's case a simple story of central government leading a process of change? Or can we also see struggles and alignments between new entrants and incumbents as in any transition in other contexts? Is the development of renewable energy simply a response to an increasing electricity demand or do we also see signs of a transformation of the electricity system? As a developing country, China may offer an inspiring case for other emerging economies. The renewable energy case may feed into a bigger question: how is it possible to surpass the old development trajectory of economic growth based on fossil fuels towards a more sustainable development pathway? Can we draw lessons from China's rapid renewable energy development for the global low-carbon transition, taking into account the specifics of the Chinese case? These types of questions have been a key motivation for this thesis.

The entry point of this thesis is that understanding wind and solar power diffusion needs a socio-technical system perspective. From this perspective diffusion is not just a technology substitution process but needs a change of grid dispatching practices, market rules, policy environment, users' behaviours and other socio-technical elements. Accordingly, this study is first and foremost a contribution to sustainability transitions studies. In this field, sustainability transition dynamics have been captured as a reconfiguration process of different socio-technical elements towards more sustainable development. The process involves the interactions among different stakeholders, especially the interactions between niche and regime actors. Transitions are often portrayed as slow processes, yet it is clear that we have to be concerned with the question of how to accelerate sustainability transition. This certainly matters because Grand Challenges, such as the climate crisis, demand a fast response. Yet fast pace brings the danger of an early lock-in to a sub-optimal pathway. Therefore, it is crucial to understand how different actors interact to shape different transition pathways. The concept of directionality captures this. It provides a focus on the directions of socio-technical change, which leads to an analysis of possible and desirable transition pathways. In this thesis I examine two options: a pathway with a focus on large-scale power plants fuelled by renewables but fitting into the existing

centralised energy system; or another option in which a distributed energy system stretches and transforms the existing centralised coal power system.

My search for theoretical insights to unpack how niche and regime actors interact to shape wind and solar power development in China led me to draw insights not only from sustainability transitions studies, in particular the multi-level perspective, strategic niche management and the geography of transitions, but also from work on the sociology of expectations and from studies on institutional work. The thesis contains three core chapters (chapters 3–5) which have been either published or submitted as journal articles.

Chapter 3 (Article One) examines the question of how niche and regime actors interact to shape niche acceleration. It focuses on the alignment dynamic between niche and regime actors. Drawing on the sociology of expectations literature, the chapter argues that expectations are key to coordinating the alignment process between niche and regime actors leading to niche acceleration. The chapter provides a novel conceptual framework to conceptualise three different alignment patterns between niche and regime actors and connects them with three stages of niche development: *slow*, *moderate* and *substantial* niche acceleration. Moreover, it offers a novel quasi-quantitative methodology to map actors' alignment dynamics following their expectation structures. It suggests a niche technology adoption rate of 16% as a threshold of niche acceleration. The paper tests the conceptual framework in two contrasting cases of wind and solar power development in China at the national level between 2000 and 2017. The research findings confirm that although the two cases follow divergent development patterns, strong alignment between niche and regime actors' expectations go hand in hand with niche acceleration.

Chapter 4 (Article Two) examines a crucial but underdeveloped concept in strategic niche management literature: niche shielding. Shielding is not only key for building up the niche, but also for speeding up the transition. It is often assumed to be a linear process of building up protection and phasing it out. This chapter makes a novel contribution to the investigation into how niche and regime actors interact to shape niche shielding dynamics from two aspects: (1) how it unfolds across multiple dimensions of the socio-technical system (S&T, political, industry, market and culture); and (2) how it unfolds across multiple scales (mainly provincial and national). It examines the empirical studies of China's wind power development in two provinces, Inner Mongolia and Jiangsu province, as well as the development at the national level. It suggests that niche and regime actors may align in certain dimensions while facing conflict in other dimensions across multiple scales. This has crucial policy implications for phasing out

shielding activities, which is more complex than realised in previous studies, which assumed that this is a linear process.

Chapter 5 (Article Three) aims to answer *what type of institutional work* niche and regime actors enact to shape the directionality of sustainability transitions. The empirical focus is to understand why solar power developments in two Chinese provinces, Inner Mongolia and Jiangsu, are shaped in two different directions. Inner Mongolia ends up with large-scale centralised solar power plants fitting into the established centralised power system, while Jiangsu province takes up distributed solar PV system and stretches and transforms its centralised power system. The chapter proposes a novel conceptual framework to examine three core aspects: (i) the portfolio of institutional work; (ii) the nature of niche–regime interactions; and (iii) the multi-scalar dimension of institutional work. The research findings suggest there is no single causal mechanism to explain each of the two transition pathways. Rather, the three proposed aspects co-evolve together during the process of socio-technical change. The chapter argues that for more radical (or transformative) directionality three developments need to take place: (1) Niche and regime actors are engaging with a portfolio of institutional work that addresses all three regime rule-set pillars (cognitive, normative and regulative) in an integrative way; (2) In this engagement regime actors participate but niche actors have a leading role; (3) Both types of actors are able to work across multiple scales.

The overall research findings of these three core chapters therefore contribute to developing a new conceptual and methodological understanding of how niche and regime actors interact to shape the speed and directionality of niche development. These contributions are discussed in greater detail in Chapter 6.

## Table of Contents

SUMMARY.....	i
Acknowledgements.....	iii
Preface .....	vi
List of Figures .....	xii
List of Tables .....	xiii
List of Abbreviations .....	xiv
Chapter 1 Introduction .....	1
1. 1 Background and motivation .....	1
1. 1. 1 Accelerating radical innovation towards sustainability.....	1
1. 1. 2 The key to understanding acceleration is to unpack niche and regime actors’ interaction dynamics.....	2
1. 1. 3 Examining wind and solar power development in China’s electricity system.....	3
1. 2 System innovation towards sustainability .....	6
1. 2. 1 Socio-technical change and transition dynamics .....	7
1. 2. 2 Actors and embedded socio-technical structures.....	8
1. 2. 3 Underdeveloped concept of niche–regime interactions and the role of actors .....	9
1. 3 Research aims and questions.....	13
1. 4 Actor interactions, alignment and niche acceleration .....	14
1. 5 Theoretical contributions and academic relevance .....	19
1. 5. 1 A general contribution: bridging the dichotomy between top-down and bottom-up approaches.....	19
1. 5. 2 Academic audience and debates.....	20
1. 6 Overview of the thesis .....	21
Chapter 2 Research design and methodology .....	27
2. 1 Process theory of socio-technical change .....	27
2. 2 Case study research design .....	27
2. 3 Data collection and analysis.....	31
Chapter 3 Article 1 .....	35
3. 1 Introduction .....	37
3. 2 Aligning expectations in sustainability transitions .....	40
3. 2. 1 Alignment between niche and regime actors through expectations.....	40
3. 2. 2 Typology of alignment dynamics between niche and regime actors’ expectations.....	41
3. 2. 3 Relating alignment patterns to niche acceleration .....	50

3. 3 Methodology .....	51
3. 3. 1 Specifying the framework for our case studies: niche acceleration.....	51
3. 3. 2 Specifying niche and regime actors.....	52
3. 3. 3 Data collection and analysis .....	54
3. 4 China's wind and solar power development.....	57
3. 4. 1 Alignment dynamics between niche and regime actors' expectations of wind power .....	57
3. 4. 2 Alignment dynamics between niche and regime actors' expectations of solar power .....	60
3. 5 Discussion.....	64
3. 5. 1 Weak alignment and slow niche development .....	64
3. 5. 2 Medium-strong alignment and moderate niche development.....	65
3. 5. 3 Strong alignment and substantial niche acceleration .....	65
3. 6 Conclusion.....	66
Chapter 4 Article 2 .....	69
4. 1 Introduction .....	71
4. 2 Shielding dynamics for niche development .....	72
4. 2. 1 Multi-dimensional niche shielding dynamics .....	74
4. 2. 2 Multiple scales of niche shielding dynamics .....	77
4. 3 Methodology and data collection .....	78
4. 4 Wind power development .....	80
4. 4. 1 National level .....	80
4. 4. 2 Inner Mongolia .....	84
4. 4. 3 Jiangsu province .....	86
4. 5 Discussion.....	88
4. 5. 1 Niche shielding dynamics across multiple dimensions and multiple scales.....	88
4. 5. 2 Implications for phasing out temporary protective spaces.....	91
4. 6 Conclusion.....	92
Chapter 5 Article 3 .....	94
5. 1 Introduction .....	96
5. 2 Institutional work and directionality.....	98
5. 3 Methodology.....	107
5. 3. 1 Case study selection strategy.....	107
5. 3. 2 Data collection and analysis .....	109
5. 4 Solar PV development.....	111

5. 4. 1 National level .....	111
5. 4. 2 Inner Mongolia: fit-and-conform pattern .....	114
5. 4. 3 Jiangsu: stretch-and-transform pattern .....	119
5. 5 Discussion.....	124
5. 5. 1 Portfolio of institutional work .....	124
5. 5. 2 Niche-regime interactions.....	127
5. 5. 3 The multi-scalar dimension of institutional work.....	128
5. 5. 4 Towards a potential conceptual framework: co-evolve process among three key aspects .....	129
5. 6 Conclusion.....	131
Chapter 6 Discussion and conclusion.....	133
6. 1 How research questions are addressed and key research findings .....	133
6. 2 Main contributions of the thesis to knowledge .....	138
6. 2. 1 Conceptual contributions.....	139
6. 2. 2 Methodological contributions.....	143
6. 2. 3 Empirical contributions .....	143
6. 3 Qualifying the scope of the conclusions.....	145
6. 4 Underdeveloped themes and avenues for future research .....	146
6. 5 Concluding remarks: escaping the past and moving towards a desired future .....	147
References .....	149
Appendices .....	164
Appendix A List the interviewees, focus group and workshop participants .....	164
Appendix B Interview questions .....	168
Appendix C Supplementary data .....	170

## List of Figures

Figure 1.1. The changes in different electric power generation from 2006 to 2017 in China .....	4
Figure 1.2. China's electricity generation mix in 2017 .....	4
Figure 1.3. Four phases of sustainability transition-S-curve niches diffusion model .....	17
Figure 1.4. Visualisation of the focus areas of the three core chapters .....	22
Figure 3.1. Historical development of installed capacity of wind and solar power in China (2001–2017). .....	39
Figure 3.2. Typology of 27 theoretically possible alignment dynamics between niche and regime actors' expectations. ....	46
Figure 3.3. Different alignment patterns between niche and regime actors' expectations. ....	49
Figure 3.4. Revised technology adoption lifecycle. ....	51
Figure 3.5. Market share of newly installed capacity per year: 2006–2017 .....	52
Figure 3.6. Key stakeholders in China's electricity sector. ....	53
Figure 4.1. Cumulative installed capacity of wind power in US, Germany, India and China: 2000 to 2017 .....	81
Figure 4.2. 2011-2018 Curtailment capacity of wind power in China .....	83
Figure 4.3. Shielding dynamics for wind power development at national level and in Inner Mongolia and Jiangsu province .....	90
Figure 5.1. Evolution of global total solar PV installed capacity 2000-2017. ....	108
Figure 5.2. Installed capacity of distributed solar PV in China- by the end of 2018. ....	108
Figure 5.3. Cumulative installed solar PV power and various application market in China from 2001 to 2018 .....	109
Figure 5.4. Institutional work and historical institutional change for solar PV development at national level .....	114
Figure 5.5. Institutional work and historical institutional change for solar PV development in Inner Mongolia and national level .....	118
Figure 5.6. Institutional work and historical institutional change for solar PV development in Jiangsu and national level .....	123
Figure 5.7. Actors adopt portfolio of institutional work shaping directionality of sustainability transitions .....	131

## List of Tables

Table 1.1. Summary of existing understandings of niche and regime interactions .....	11
Table 1.2. Summary of the three core chapters .....	23
Table 1.3. Declaration of contribution by PhD candidate to the three journal articles .....	25
Table 2.1. Secondary data sources.....	32
Table 2.2. Overall research design for chapters 3–5.....	33
Table 3.1. Content of expectations at the landscape, regime and niche level in five dimensions of the socio-technical system .....	55
Table 3.2. Niche and regime actors' alignment of expectations of wind power niche development (2000–2017).....	57
Table 3.3. Niche and regime actors' alignment of expectations of solar power niche development (2000–2017).....	61
Table 4.1. Five dimensions of niche shielding dynamics.....	76
Table 5.1. Mechanisms of how institutional work towards shaping different pillars of institutions .....	102
Table 5.2. Operationalisation of three institutional pillars .....	111
Table 5.3. Divergent portfolio of institutional work in two provinces .....	124
Table 5.4. Propositions on how portfolios of institutional work adopted by niche and regime actors across spatial boundaries shapes the directions of sustainability transitions in terms of fit-and-conform and stretch-and-transform pattern.....	129



## List of Abbreviations

CASTED- Chinese Academy of Science and Technology for Development

CEC-China Electricity Council

CEO- Chief Executive Officer

CHP-Combined Heat and Power

CNKI- China National Knowledge Infrastructure

CWEA-Chinese Wind Energy Association

DSPV-Distributed Solar Photovoltaics

GWEC-Global Wind Energy Council

IEA-International Energy Agency

IRENA- International Renewable Energy Agency

MLP- Multi-level Perspective

NDRC-National Development and Reform Commission

NEA-National Energy Administration

NGO- Non-Governmental Organisation

RE- Renewable Energy

S&T-Science and Technology

SNM-Strategic Niche Management

STS- Science and Technology Studies

TIPC-Transformative Innovation Policy Consortium

TIS-Technological Innovation System

## Chapter 1 Introduction

### 1. 1 Background and motivation

#### 1. 1. 1 Accelerating radical innovation towards sustainability

“To sufficiently limit the rise in global temperatures, energy use would have to be completely decarbonised in less than 50 years, even amid the expected tripling of the world’s economy by 2060. This means renewable energy – already growing fast over the past decade – must grow at least seven times faster” (IRENA, 2017, p. 4). This thesis explores how to accelerate renewable energy development.

The focus on acceleration towards sustainable energy provision brings a dilemma to the fore between rapid and radical change (structural and transformative change). On the one hand, renewable energy as radical innovation requires not just technology substitution but also fundamental transformation at the system level. The process involves not only technological innovation but also a change of other social elements: policies, regulations, market rules and users and producers’ behaviours. Because of the system’s lock-in and structural barriers, diffusion of renewable energy generally goes slowly (Jacobsson and Johnson, 2000; Negro et al., 2012). An acceleration of its diffusion may, however, lead down a path where large-scale power plants are fitted into the existing centralised power system (i.e. less transformative change). On the other hand, if system changes are too radical, for example, promoting a more distributed energy system, they may encounter fierce resistance from incumbents. This may lead to failure or slower diffusion.

In this thesis I investigate both aspects of system change towards sustainability. I employ two concepts: speed and directionality. Speed refers to the pace of change (whether it is slow or rapid). As pointed out by Geels and Schot (2010), radical innovations can either be sudden and lead to creative destruction, or they can be slow and proceed in a stepwise fashion. Directionality refers to a spectrum of potential directions of socio-technical change (whether that change be incremental or radical). In this thesis I focus on two possible directions: centralised versus decentralised electricity provision. I am interested in exploring how actors interact to shape a more sudden and rapid system transformation towards sustainability while also shaping its directionality.

The speed aspect is particularly important given the urgency of the climate crisis. Speed is discussed in recent debates on the temporal dynamics of energy transitions moving away from fossil fuels to tackle climate change (Bromley, 2016; Fouquet, 2016; Grubler et al., 2016; Kern and Rogge, 2016; Smil, 2016; Sovacool, 2016). Sovacool (2016) challenged the conventional

understanding that energy transition generally takes three to five decades (Grin et al., 2010) and argued that the future energy transition could be accelerated, as had been observed in some previous cases. This is supported by Kern and Rogge (2016), who observed that the recent low-carbon energy transition can be sped up with a conscious governance approach working proactively with the involvement of multiple actors. However, Grubler et al. (2016) and Smil (2016) argued that energy transition involves fundamental system changes across multiple scales and multiple dimensions – technologies, infrastructures and organisational and institutional settings – which makes it hard to steer and accelerate. The underlying question in this debate is whether intentional steering works for a transition that has been perceived as a complex process and demands coordination among different stakeholders. An additional question is how speeding up will influence the directionality of transitions and perhaps may create lock-in to a centralised electricity provision.

#### 1. 1. 2 The key to understanding acceleration is to unpack niche and regime actors' interaction dynamics

To resolve the debate on whether actors can accelerate energy transition and how it will influence the directionality, I will unpack the alignment dynamics between new entrants (niche actors) and incumbent actors (regime actors), which have been argued as contributing to the upswings and downturns of transitions (Geels et al., 2012). It has been argued in sustainability transition studies that strategic support from regime actors can stimulate niche acceleration (rapid transition). Grin et al. (2010) recognised that working with incumbent actors, who have many resources, competence and 'mass', may contribute to the speed of transition. However, while regime actors may be interested in exploring niches, they are less likely to collaborate with niche actors for the purpose of niche acceleration since this may affect their vested interests. Moreover, strong interventions from regime actors generally lead to less radical transformative change (Smith, 2007; Coenen et al., 2010). It is assumed in the literature that incumbents have too many vested interests and will try to hinder or contain radical innovations (Schot and Geels, 2008). For radical innovation it is better to work with regime outsiders, who think outside the box and have new ideas (Geels and Schot, 2010).

To resolve the question about the role of various actors, I argue that it is necessary not only to get a better understanding of the specific roles that niche and regime actors play during the transition process, and how they build a shared agenda and vision to shape transition dynamics, but also to ask under what conditions regime actors give up resistance and start to collaborate with niche actors for niche acceleration. Therefore, instead of emphasising regime actors' resistance as conventional transitions studies do, I unpack the alignment dynamics between

niche and regime actors in order to investigate how their alignment dynamics shape the speed and directionality of niche development.

Here, I should point out that there are some differences between the notion of new entrants and incumbent actors and the notion of niche and regime actors. New entrants and incumbents are mainly used in strategic management literature, with an emphasis on how the competition between the two in the market shapes industry dynamics, while the notion of niche actors and regime actors is mainly used in sustainability transitions literature. Here the emphasis is on actors following certain rule sets from a sociological perspective. Niche actors follow different rules (and incentives) from regime actors. In recent years, the transition literature has started to explore the notions of new entrants and incumbents and has begun to connect with strategic management studies (Geels, 2010; Farla et al., 2012; van Mossel et al., 2018). I follow this trend. Therefore, in this study, the terms niche actors and new entrants are used interchangeably, as are incumbents and regime actors, but with the understanding that incumbents can also be niche actors especially when they start to question regime rules and share the visions of niche actors. For example, the State Grid company and some of the larger thermal power companies are incumbent actors but have also played a role as niche actors recently, by strategically supporting and investing in renewable energy in China (Yang et al., 2020). In this case, I will treat incumbents as both regime and niche actors when they are involved in both regime and niche activities. In other circumstances, new entrants could also compete with regime actors trying to win market share from them. I will only distinguish the incumbents and regime actors when it is necessary.

### 1. 1. 3 Examining wind and solar power development in China's electricity system

In this thesis, I will analyse empirical insights from wind and solar power development in China's electricity system between 2000 and 2017. During this period, both solar and wind power have undergone astonishing niche acceleration (Yang et al., 2020). China now has the world's largest renewable energy industry and is a world leader in installed capacity of wind and solar power. In 2017, its new wind installed capacity contributed to one-third of the global market and its new solar installed capacity contributed to one-half of the global market. In the domestic market, as depicted in Figure 1.1, in 2000, both wind and solar power were virtually non-existent in the country's electricity mix, while in 2017, renewable energy contributed 25.21% of its total electricity power generation, of which hydro, wind and solar power contributed 18.61%, 4.76% and 1.84% respectively (Figure 1.2).

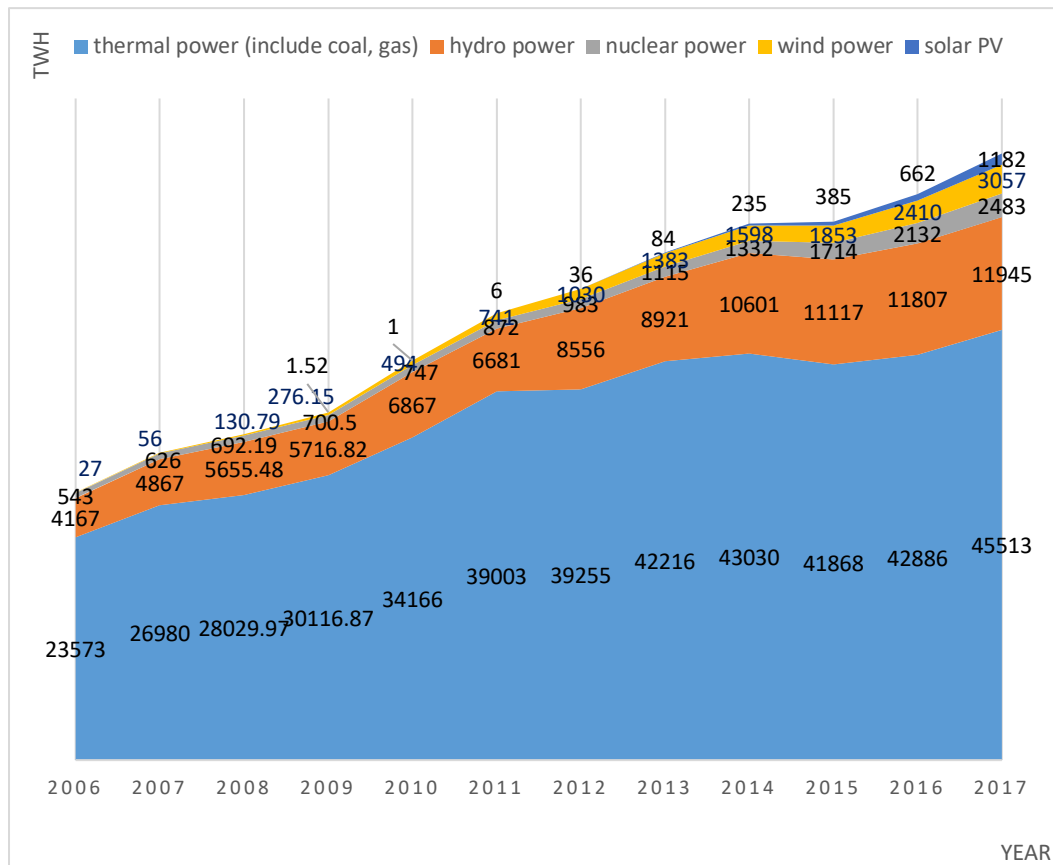


Figure 1.1. The changes in different electric power generation from 2006 to 2017 in China  
Source: author's own, based on statistical data from National Energy Administration

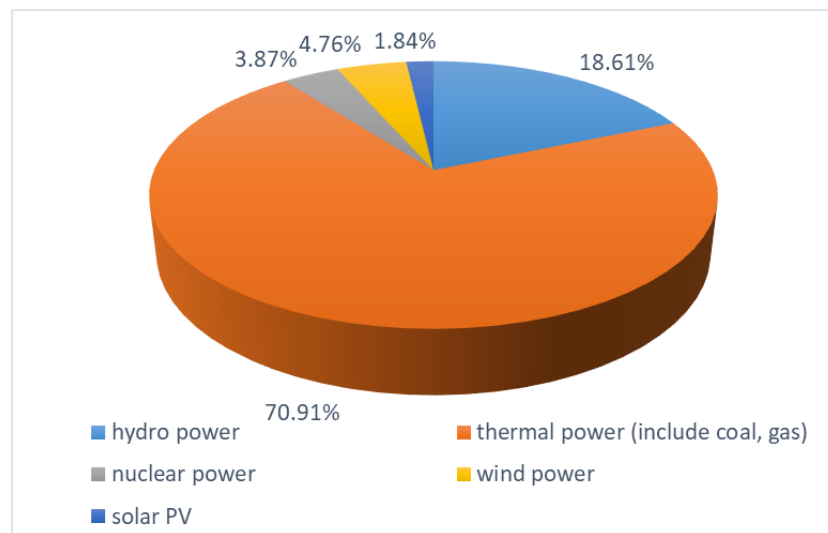


Figure 1.2. China's electricity generation mix in 2017  
Source: author's own, based on statistical data from National Energy Administration

Meanwhile, China is still the largest global coal power consumer and the world's largest CO<sub>2</sub> emitter. As an emerging economy moving rapidly towards urbanisation and industrialisation, its electricity demand is still increasing (Figure 1.1). In 2017, its electricity consumption accounted

for one-quarter of the global market and its global share is expected to rise around 30% by 2035, based on a new policy scenario by the International Energy Agency (IEA, 2019). Therefore, its pace moving towards low-carbon transition is of significance to the whole world's commitment to reduce carbon emissions (Urban, 2014).

China made its commitment to reduce its carbon intensity (CO<sub>2</sub> emissions per unit of GDP) by 60–65% compared with the 2005 levels by 2030 (CarbonBrief, 2015). To achieve this goal, improving the proportion of low-carbon energy in the energy mix has been an important strategy, with a target of increasing non-fossil fuel in its primary energy consumption to 20% by 2030 (NDRC and NEA, 2016b). Since 2012, domestic environmental issues, especially air pollution, have been visible, which has heavily drawn people's attention to the need to restructure the industry and to reduce the proportion of coal power in its energy mix (Urban et al., 2012; Yang et al., 2020). To mitigate domestic air pollution, the Chinese government issued the "Air Pollution Action Plan" (State Council, 2013), in which it states that controlling the burning of coal and promoting renewable energy is one of the most important measures to transform its electricity system into green and low carbon one.

The idea that a move towards clean and low carbon is necessary is widely shared among Chinese government officials (Geall, 2017; Geall and Ely, 2018). They see the need to rapidly drive the whole electricity system towards renewable energy (RE) (NDRC and NEA, 2016b). The Chinese words, *zhuanxing* (transition), *geming* (revolution) began to appear in policy documents for the first time in recent years, illustrating this ongoing process of low-carbon transformative changes. In the 19<sup>th</sup> Communist Party of China (CPC) National Congress report, Chinese central government showed its determination to transform the country's current coal dominated energy system to promote the transition of energy production and consumption structures, and to build a clean, low-carbon, safe and efficient energy system (Xi, 2017).

These developments raise several questions: Why is China, a country with an entrenched coal power system, opening up for rapid development of renewable energy. Is China's case a simple story of a central government initiating a change process? Or is the story more complex, and is the central government also subject to struggles and alignments between new entrants and incumbents? And why did the central government decide on a new direction towards renewable energy? Does the development of renewable energy simply fit into its need to address increasing electricity demand, or is there a genuine sense of need for transformative change of its electricity system? Is the development focused on providing a centralised provision of energy or is there also space for decentralised options? Moreover, can we draw lessons from China's rapid

renewable energy development for global low-carbon transition, taking into account the specifics of the Chinese case?

To address these broader questions and to develop my research questions, I will first harness insights from the field of sustainability transitions studies. While bearing in mind that most sustainability transitions empirical studies have been conducted in the context of western, developed countries, I would like to investigate what theoretical insights sustainability transitions studies offer to explain the specific case of China and ask whether these insights are sufficient. To what extent does China's case of fast low-carbon transition challenge the conventional understanding of sustainability transitions in which it is generally assumed to require several decades? Does the case of China demonstrate a different development model for rapid transition? How is this rapid transition combined with exploring both centralised and decentralised options? What can transition studies learn from China's empirical insights? What lessons can we draw from China for other countries undergoing or aiming for transformative change towards sustainable development? These types of questions will be discussed in the final Chapter 6, based on this study's insights.

## 1. 2 System innovation towards sustainability

Sustainability transitions studies have made prominent contributions to the study of environmental innovation and sustainable development. The field has investigated the co-evolving process between technological change and societal change towards sustainable development. Various conceptual frameworks have been developed (Grin et al., 2010; Markard et al., 2012). For example, transition management (Kemp and Loorbach, 2003; Kemp et al., 2007), technological innovation system (TIS) (Hekkert et al., 2007; Bergek et al., 2008; Markard and Truffer, 2008), strategic niche management (SNM) (Kemp et al., 1998; Hoogma et al., 2002; Schot and Geels, 2008), and multi-level perspective (MLP) (Geels, 2002, 2004; Geels and Schot, 2007). The concept of transition management mainly focuses on a participatory approach to steer and manage the ongoing transition process, while the concept of TIS mainly focuses on niche development with limited attention given to regime dynamics (Markard and Truffer, 2008). Looking for theoretical tools to conduct retrospective studies to examine the long-term transformative change process in China's electricity system, this thesis draws insights from SNM and MLP that have addressed socio-technical system change dynamics that fit the purpose of this study.

### 1. 2. 1 Socio-technical change and transition dynamics

Addressing sustainability issues requires a broad understanding of innovation, which should go beyond a focus on technological change that refers only to the development of new products, processes or services at the firm level (Grin et al., 2010; Smith et al., 2010). A sustainability transitions perspective invites a focus not only on technological innovation but also on social change. The basic tenet is that co-evolutionary processes between material and social elements forge to form well-aligned socio-technical configurations that influence the functionality and development of a system (Grin et al., 2010). Accordingly, innovation needs to be conceptualised at a system level that involves changes in production, distribution and consumption (Geels, 2004, 2005).

MLP distinguishes three heuristics for a study of socio-technical system transition dynamics (Rip and Kemp, 1998; Geels, 2002): niche, socio-technical regime and landscape. It captures the socio-technical change as a result of interactions between these three different levels. As a result of the strongly aligned socio-technical configurations, socio-technical changes follow a set of rules which are conceptualised as a socio-technical regime. These rules thus generate major path dependencies in the industrial sectors aligned with the regime. This implies that the regime can force new technological alternatives to fit-and-conform (Smith and Raven, 2012) with the established technical and institutional structures (Foxon, 2002; Jacobsson and Bergek, 2004; Markard and Truffer, 2006).

The concept of socio-technical regime builds on the evolutionary economics thinking of technological regime (Nelson and Winter, 1982) and technological paradigm (Dosi, 1982; Dosi et al., 1988). Rip and Kemp (1998) and Schot (1998) expanded this understanding with the sociological category of *rules*. Technological regime is defined as: “the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures” (Rip and Kemp, 1998, p. 340). Following Scott (1995), Geels (2004) further developed the *rule* concept. He introduced distinctions between regulative, normative and cognitive rules. Examples of cognitive rules are beliefs, guiding principles and searching heuristics. Normative rules include values and social norms. Regulative rules include regulations, standards and laws. The alignment of these rules reinforces the stability of the socio-technical change. When these rules are well established, innovations still occur but follow an incremental trajectory. Thus, to shape socio-technical change towards a more sustainable development direction, it is crucial to replace or reconfigure these dominant rules. As articulated by Schot and Kanger (2018), these rules can be



perceived as the genotype and the socio-technical system as the phenotype of a transition process. This implies that the change of these rules is more fundamental for transition dynamics, and an investigation of the underlying mechanisms of socio-technical system transformation should conceptualise it not only as a co-evolutionary process among different socio-technical elements but also as an institutionalisation process (Fünfschilling and Truffer, 2014). A transition can be defined as a change of the socio-technical regime (a rule-set) (Geels and Schot, 2010).

The notion of a niche refers to an environment in which regime rules are not dominant and therefore new types of behaviours and preferences can develop. Niches offer protective spaces that allow the emergence of radical innovations and experimentation with new rules (new standards, new beliefs and new values). SNM studies identify three mechanisms crucially important for niche development: learning, expectations navigation, and social network building (Kemp et al., 1998; Schot and Geels, 2008). Landscape refers to the external environment of socio-technical systems (Rip and Kemp, 1998; Schot and Geels, 2007). It consists of a number of trends and shocks that influence the dynamic interaction between niches and regimes. The changes at landscape level are generally very slow, although they may appear suddenly in the form of shocks (Van Driel and Schot, 2005). They often develop over a longer time period.

### 1. 2. 2 Actors and embedded socio-technical structures

MLP has been defined as “a middle-range theory that combines specific elements from other theories..., and as such it is geared to answering particular questions on the dynamics of transitions” (Geels and Schot, 2010, p. 19). Its theoretical assumptions of socio-technical change and its underlying dynamics originate from cross-overs between different sub-disciplines (Geels and Schot, 2010), in particular science and technology studies (STS) and evolutionary economics (Nelson and Winter, 1977; Dosi, 1982; Nelson and Winter, 1982; Freeman and Louçã, 2001), and later on from institutional theory as well as social theory, in particular the idea of structuration (Giddens, 1984).

From a social theory perspective, the three different levels – niche, regime and landscape – can be conceptualised as systems with different stabilised socio-technical structuration processes. Defined by Geels and Schot (2010), each level is conceptualised as a heterogeneous socio-technical configuration. “The relationship between the three levels can be understood as a nested hierarchy, meaning that regimes are embedded within landscapes and niches within regimes” (Geels and Schot, 2010, p. 18). Therefore, the three levels refer to different degrees of structuration, stability and coordination. The socio-technical regime refers to the stabilised socio-technical configuration with dominant institutional patterns, while the landscape represents the exogenous environment of the socio-technical system. The niche is a separate

selection environment offering protective spaces that shield against selection pressure from the regime and thus allowing the emergence of radical innovation and change (Schot and Geels, 2007). Therefore, niche actors are more likely to play a role as institutional entrepreneurs that shape alternative socio-technical configurations (Fünfschilling and Truffer, 2014). The concept of niche has been elaborated on and studied under the heading of strategic niche management (Schot et al., 1994; Kemp et al., 1998; Rip and Schot, 2002; Schot and Geels, 2008).

### 1. 2. 3 Underdeveloped concept of niche–regime interactions and the role of actors

Recognising the difficulties of escaping the socio-technical regime, the early stage of transition studies predominantly focused on how to stimulate the emergence of radical innovation through niches, which play a role as protective spaces. More recently a focus emerged on how novelties (radical innovations) escape from the protective spaces to finally shift the regime (Kern et al., 2014; Kern et al., 2015; Kivimaa and Kern, 2016). This is perhaps also an even more challenging process than niche creation (Schot and Geels, 2008). As argued by Geels and Schot (2010), “the core problem in transition is not the emergence and development of novelties, but their relationship with this existing regime” (p. 27). The diffusion of niches is largely influenced by the existing regime and may fail to scale up when encountering mainstream selection pressures (Hommels et al., 2007). The niche–regime interaction is especially crucial for niche scale-up and acceleration (Geels and Schot, 2010). For example, Markard (2018) argued that niche–regime interactions will be key for the second phase of niche acceleration in the global low-carbon energy transition.

Although articulated niche–regime interactions are key for niche acceleration, MLP has offered limited understanding of the mechanisms of their interactions, under what conditions the two interact, and how this interaction shapes the speed and directionality of niche development. In particular, it offers limited insights on the proactive roles of actors in shaping their interactions. This thesis therefore addresses two underdeveloped aspects: niche–regime interactions and, more generally, the role of actors in shaping niche acceleration.

Recently several studies attempted to examine the interactions between niche and regime during the transition process. Smith (2007) studied how green niche actors translate socio-technical practices that developed in niches to influence incumbent regimes. Elzen et al. (2012b) investigated how niche actors anchor other niches or existing regime structures to stabilise novelties. Hess (2016) identified that niche actors can adopt political strategies, for example, by building political coalitions with supportive political parties or with industry sectors which countervail regimes or with social movements for niche growth. Smith and Raven (2012) argued that narratives are important political strategies adopted by niche actors to empower niches,

either to fit into the existing regime and adapt to the regime's environment, or to stretch and transform the regime environment. However, there is a key bias in these studies: they treat niche–regime interactions as a bottom-up approach, focused almost entirely on a uni-directional niche-actor-oriented process (see criticism by Turnheim and Geels (2019)).

Ingram et al. (2015) identified that niche and regime interactions are more complex processes depending on their compatibility and complementarity. They concluded that when niches align assumptions, practices and rules with regimes it can accelerate niche diffusion, and that a conflict among these elements may constrain niche diffusion. This argument is in line with the two different strategies for transitions identified by Raven (2007), who argued that radical innovations can either build internal momentum through niche accumulation or actors can adopt hybridisation strategies and start with innovations that are close to the regime then enact alternative trajectories towards more radical transformation. In the latter strategy, regime actors are recognised as capable of driving transformative change, yet this may lead to a mere regime optimisation pathway (Nill and Kemp, 2009; Kern et al., 2015). Aligning with insights from SNM studies, Diaz et al. (2013) identified networking with regime actors who hold resources as a key strategy for niche actors to expand niches. However, these studies have limited understanding of how the niche and regime actors engage with institutional changes, which are key for transition dynamics.

Smink et al. (2015a) advanced our understanding of why the collaborations between niche and regime actors are extremely difficult; they attributed this difficulty to the two following different institutional logics (referring to the practices and underlying belief systems that guide actors' behaviour and thinking; see Smink et al. (2015a) p. 226). They argued that boundary spanners, actors who can span niche and regime boundaries, are crucial for building mutual understanding and productive working relationships between niche and regime actors. Their studies implied that relationships between niche and regime actors evolve along with their interactions and that niche and regime actors can build productive networks contributing to niche development when regime actors start to question their cognitive beliefs and build shared understanding with niche actors.

As criticised by Turnheim and Geels (2019), niche–regime interactions have been predominantly conceptualised as a niche-actors-oriented bottom-up approach. A more symmetrical analysis of niche–regime interactions is needed that also accommodates the possible active role of incumbent actors in niche development (Turnheim and Geels, 2019). Mylan et al. (2019) offered a useful perspective to examine niche and regime interactions as a societal embedding process. They categorised four different selection environments and indicated that niche and regime

interactions may follow different patterns in these four selection environments. However, it seems problematic to distinguish typologies of transition pathways as driven by either niche actors or regime actors as a transition generally requires collective actions between the two. In addition, the pathway needs to accommodate the notion that the interaction patterns between niche and regime actors may evolve at different stages of transition. Table 1.1 summarises the existing understandings of niche–regime interactions in sustainability transitions studies.

Table 1.1. Summary of existing understandings of niche and regime interactions

Concepts	Mechanisms of niche and regime actors' interactions	Aspect of transition dynamics	Key literature	Criticism
<i>Translating</i>	Translation of socio-technical practices across levels (niche, regime)	Shaping regime	Smith (2007)	One way interactions; The bias of a bottom-up approach, focused almost entirely on niche actors; Niche countervailing resistance from regime; (see criticism by Turnheim and Geels (2019) and Mylan et al. (2019))
<i>Anchoring</i>	Political strategies	Shaping regime	Elzen et al. (2012b)	
<i>Empowering</i>	Narrative strategies	Aiming to change regime-level selection environments to facilitate the diffusion of niche technologies	Smith and Raven (2012); Kern et al. (2015); Raven et al. (2016); Verhees et al. (2013)	
<i>Political coalitions</i>	Niche actors formalise political coalitions with political parties or social movements to countervail resistance from incumbent actors	Stabilising niches	Hess (2016)	
<i>Networking activities</i>	Niche actors enrol regime actors with more resources	Expand niches	Diaz et al. (2013)	Niche-actor-oriented with collaborations with regime actors; Niche-level focused; Lack insights of how niche and regime actors interact to shape institutional change
<i>Knowledge flows</i>	Knowledge flows from niche-innovations into regime	Expand niches	Ingram et al. (2015)	
<i>Boundary spanning</i>	Niche–regime interactions as a	Evolving understanding of	Smink et al. (2015a)	

	process of shaping institutional logics	niche–regime interactions		
<i>Societal embedding process</i>	Niche–regime interactions as societal embedding process; Multi-dimensional interactions; Bi-directional interactions	Focus on transition typology;	Mylan et al. (2019)	Either niche-actor-oriented or driven by regime actors; Lack insights into how their interactions unfold; Lack insights into evolving proactive role of actors in shaping institutional change
<i>Niche accumulation or hybridisation</i>	Either through building internal momentum or adopting hybridisation strategies	Patterns of strategies in transition process	Raven (2007)	

Moreover, sustainability transitions studies have been criticised on the grounds that insufficient consideration has been given to how much leeway actors really have in pursuing sustainability transitions within an existing system (Geels, 2011; Farla et al., 2012; Fischer and Newig, 2016). Farla et al. (2012) argued that transition studies lack an understanding of the corresponding roles of niche and regime actors for transition dynamics, and very little discussion on the interactions between these two types of actors is visible in the literature.

The transition process is often perceived as a rather substitutive “David and Goliath” type of transformation (Hockerts and Wüstenhagen, 2010). However, this simple view of conservative incumbents fighting against revolutionary niche actors has recently been criticised as being too reductionist (de Haan and Rotmans, 2018; Mylan et al., 2019). The treatment of regime actors as barriers will lead to a “tendency to treat regime transformation as a monolithic process”, which neglects the important differences in context (Smith et al., 2005). In some cases, “incumbents can be drivers of transformations of the energy system both in terms of technological development and regulatory adaptation” (Stenzel and Frenzel, 2008, p. 2655). For example, in Spain the utility companies proactively drive the diffusion of wind power (Stenzel and Frenzel, 2008). Recent studies on the capital-intensive industries have identified that regime actors can orient themselves towards niche innovations (Bergek et al., 2013; Berggren et al., 2015). New sustainability transitions pathways can thus arise from regime actors driving the transition process (Turnheim and Geels, 2019).

The above debates on the role of niche and regime actors for sustainability transitions indicate that knowledge is still lacking on how the two (niche and regime actors) play a role in shaping transition dynamics. More conceptual and empirical studies are needed to respond to this research gap. Instead of adopting a homogeneous understanding of regime actors as resistant to change, this thesis takes a more empirically open and explorative approach and investigates their respective roles for understanding the speed and directionality of niche development.

### 1.3 Research aims and questions

The current literature on niche–regime interactions has examined specific mechanisms (for example, knowledge accumulation, resource mobilisation, political coalitions) on how niche and regime actors interact. Generally, the literature is biased towards treating transition as a bottom-up process where niches influence regimes. Many authors have generally attributed regime shifts to landscape or/and niche pressures, while less emphasis is given to the proactive interactions between niche and regime actors. It is still generally unclear how this interaction process plays out and shapes niche development patterns. In particular, I am interested in the niche acceleration phase when the niche development is speeding up, and its directionality may become clearer and locked into a specific development pattern. The existing conceptual and methodological understanding of how niche and regime actors interact in order to shape niche acceleration is still limited.

Based on these considerations this thesis addresses the following overarching research question:

***How do the interactions between niche actors and regime actors shape wind and solar power niche acceleration in China's electricity socio-technical system between 2000 and 2017?*** There are three sub-questions to help me address this research question.

The first sub-question addresses the pace of change (whether it is slow or rapid). It has been suggested by sustainability transitions studies that the strategic support from regime actors for niche actors contributes to the speed of niche acceleration (Hoogma et al., 2002; Elzen et al., 2012a; Geels et al., 2012). Therefore, I ask:

- 1) How do the alignment dynamics between niche actors and regime actors unfold during niche development? And in particular, how do their alignment dynamics shape niche acceleration?

Niches need the build-up of a specific selection environment to shield against selection pressure from the socio-technical regime. This shielding is often provided by regime actors and is crucially important for shaping both the speed and directionality of niche development. Therefore,

understanding how niche and regime actors interact to shape the shielding dynamics would be key for explaining niche acceleration. This leads me to ask a second sub-question:

- 2) How do niche and regime actors interact to shape niche shielding dynamics?

The third sub-question addresses the directionality of niche development (whether it is incremental (and follows a fit-and-conform pattern) or radical (and follows a stretch-and-transform pattern), and it investigates:

- 3) How do niche and regime actors interact to shape the directionality of sustainability transitions?

#### 1. 4 Actor interactions, alignment and niche acceleration

In this section I will first elaborate on the two main concepts in my research question: alignment between niche and regime actors, and niche acceleration. Alignment between niche and regime actors will be defined as a result of niche and regime actor interactions across multiple regime dimensions, multiple selection environment layers<sup>2</sup> and multiple spatial scales. Then I discuss how this study defines niche acceleration, before I suggest three mechanisms through which niche and regime actors interact and align to shape the speed and directions of niche development. These three mechanisms are: expectation alignment, niche shielding and institutional work enacting.

I start with a discussion on dimensions, layers and scales, explaining why they matter. Regimes consist of a number of dimensions. Geels (2004) distinguished five key dimensions of the socio-technical regime (science, technology, policy, socio-cultural, and user and market), each with associated institutions, actors and resources that explain dynamic stability and unfolding trajectories in socio-technical change. Smith and Raven (2012) added industry structures, thus coming up with six dimensions. They argue that each dimension acts to exert selection pressures on niche innovations, with consequences for how niche and regime actors interact. In this thesis, I will combine the two dimensions of science and technology from Geels (2004) into one dimension as science and technology since both operate closely together in the context of my case study. My study will therefore focus on the following five dimensions: science and technology, industry strategy, policy, market, culture (for further specifications please see chapters 3 and 4).

Studying multiple regime dimensions contributes to refining the heterogeneous understanding of divergent strategies adopted by regime actors. It can be seen as a response to criticisms of

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<sup>2</sup> Following Rip (2012), I use the terminology “layer” to refer to the three levels of MLP, niche, regime and landscape. This is to avoid confusion with the administrative levels that refer to the national and provincial level.

transition studies that have treated regime change too much as a monolithic process (Berkhout et al., 2004; Smith et al., 2005). Recognising regime change as a multi-dimensional process also clarifies the semi-coherent nature of the socio-technical regime (Geels, 2004; Geels and Schot, 2007; Geels, 2011). Since alignment among dimensions is often not fully developed, regime rules are not fully coherent.

In recent literature, some scholars started to use the regime dimensions to investigate how niche and regime actors' interactions vary across them. Mylan et al. (2019) categorised four different social environments (representing regime dimensions) within which new products can be embedded: business environment, policy environment, wider publics and culture, and user environment. They argued that niche and regime interactions may perform different activities in these four different environments. They measured differences in terms of whether actors follow fit-and-conform or stretch-and-transform strategies.

In addition to regime dimensions, following MLP, niche and regime actors interact across three different levels or layers. These layers can be seen as three different selection environments: landscape, regime and niche. This thesis incorporates these layers through its focus on how niche and regime actors' interactions are shaped by their expectations of future development within these selection environments. That is to say, niche and regime actors' interaction dynamics are influenced not only by their expectations of future niche development, but also by their expectations of future regime change and landscape development. The transition dynamics are therefore shaped by niche and regime actors' expectations across these three layers.

Finally, I investigate how niche and regime actors interact across multiple scales to shape niche acceleration. As proposed in the geographical studies of sustainability transitions, actors work across multiple scales (local, provincial, national and global levels). Accordingly, they can mobilise institutional conditions at different scales to fulfil their ambitions, and this mobilisation process shapes both the speed and directions of niche development.

While the insights of multi-scalar understanding of niche development have been introduced in sustainability transition studies, they have predominantly focused on the national level, ignoring important regional differences (Dewald and Truffer, 2012; Lawhon and Murphy, 2012; Truffer and Coenen, 2012). As criticised by Coenen et al. (2012), the lack of insights into local or regional variations and interpretations in transition frameworks (such as the MLP) comes with the risk of treating the regime as a homogeneous structure. The general tenet in the field of economic geography is that institutional arrangements are territorially embedded (Hansen and Coenen,



2015; Murphy, 2015). This idea provides a window of opportunity to understand regional varieties of transition pathways. Several studies have acknowledged how the divergent local and regional regime contexts can influence the emergence of niches (see the review by Hansen and Coenen (2015)). Longhurst (2015) argues that the crucial role of localised cultural norms, values, worldviews and networks are key for creating the socio-cognitive protective space for a specific set of innovation. Raven et al. (2008) have also stressed the geographical contextualisation of niche experiments.

These insights from a geography of transition perspective have predominantly articulated the crucial role of spatial unevenness for niche development. I take these perspectives further by focusing on the multi-scalar dimension of regimes building on a criticism of the MLP that the three layers – niche, regime and landscape – need more explicit conceptualisation of multiple scale (with respect to territorial levels) (Coenen et al., 2012). The relevant point for this thesis is that niche–regime interactions are mediated through complex scalar processes precisely because socio-technical regimes are situated at various territorial levels (Coenen et al., 2012; Raven et al., 2012; Bridge et al., 2013). As discussed in chapters 4 and 5, the divergent socio-technical transitions at the provincial level can be traced to niche and regime actors proactively shaping socio-technical changes at multiple scales.

The identification of dimensions, layers and scales allows me to observe different interaction patterns between niche and regime actors during complex transition dynamics across these aspects. These patterns shape niche acceleration. Transition has been defined as the movement or shift from one to another socio-technical regime. It unfolds with two processes, niche development and regime destabilisation. Niche acceleration is a particular phase in the niche development process. This can be defined from two aspects, speed and directionality. In this thesis, I will study directionality by making a distinction between two patterns in terms of how their radicalness departing from the dominant socio-technical regime. Following Smith and Raven (2012) these are called a fit-and-conform and a stretch-and-transform pattern. Since the speed of niche development has been less defined, I will elaborate more on how this thesis studies the speed aspect.

The speed of niche development can be seen as a diffusion process, not of a technology or a product but of a system. Therefore, Schot and Geels (2007) suggest measuring niche development and acceleration in terms of the adoption rate of niche rules. These rules represent the system. In this scheme regime destabilisation is measured as a process of abandoning rules. With the wide diffusion of niche rules, niches will be stabilised and grow into potential socio-technical regime. Schot and Geels (2007) have argued that some stabilisation of rules is a

necessary precondition for wide adoption and thus niche acceleration. This hypothesis has been confirmed in historical analysis of the development of the automobile regime (Kanger and Schot, 2016). A remaining question is whether we can identify a threshold of stabilisation that will trigger niche acceleration. In my thesis I propose to use insights based on technology diffusion studies, in particular the work of Rogers (2010), to define a threshold of 16% of niche technology adoption as niche acceleration (see Figure 1.3). Diffusion studies have shown that when 16% of the users adopt a new technology, new users are more inclined to follow a social norm, i.e. adopt a new technology because others are doing this. This may be taken as a sign of stabilisation since actors do not explore new rules but accept them. The work of Rogers leads me to propose the following diffusion pattern. When the adoption rate of a new technology is below 2.5 % niche development is slow; this is the pre-development phase. When the adoption rate is between 2.5 % and 16 % niche development is moderate; this is the take-off phase. And when the market share is above 16 %, we enter the niche acceleration phase with substantial niche development. For more detail see Chapter 3 (Yang et al., 2020).

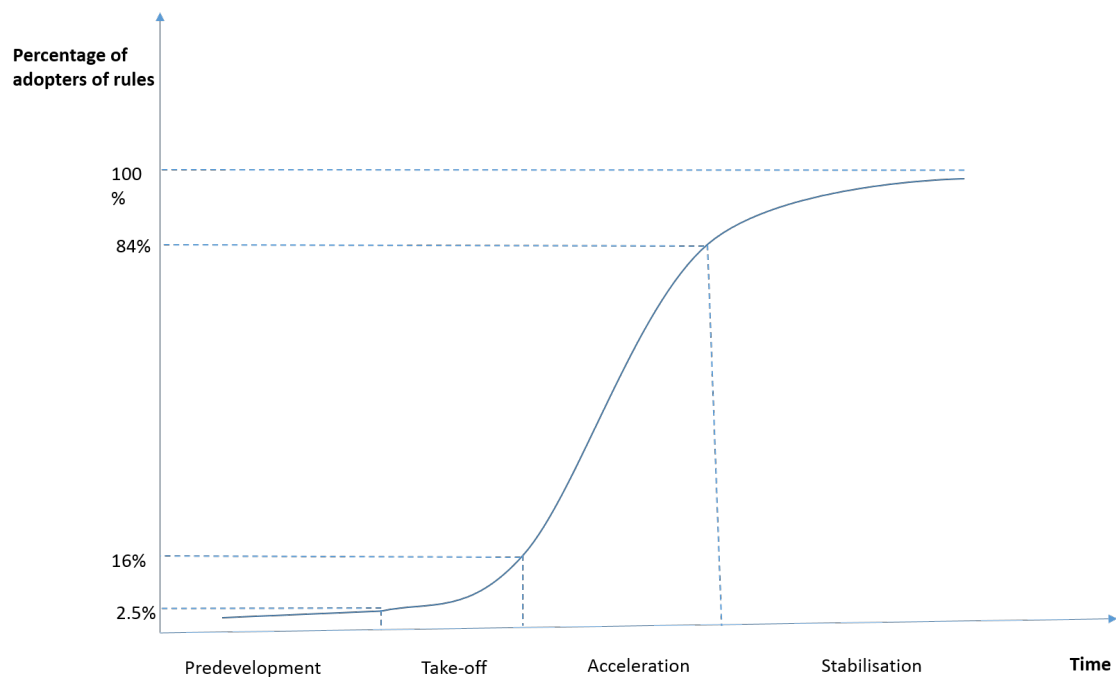


Figure 1.3. Four phases of sustainability transition-S-curve niches diffusion model

Source: author's own

This idea of a threshold has been argued implicitly in the sustainability transitions literature. For example, Rip (2012) argued:

While rules (including possible standards) are proposed all the time, explicitly or de facto in ongoing activities, important is the shift from them being tentative, which have to be defended all the time, to authoritative, which shape action, as a force in their own right. In other words, a “reversal” occurs, from being driven to being a driver. This is

characteristic for how the regime layer comes to shape activities in ongoing practices. After the reversal, there will be dynamics of its own, e.g., consideration and improvement of the rules (Rip, 2012, p. 162).

This idea of reversal is similar to the idea of a threshold. From insights proposed by Rip, after the reversal the rules are more stabilised, and the directions are locked into one certain pattern. Therefore, in this thesis, I define niche acceleration which does not feature only with rapid niche diffusion rate but also with stabilised direction.

This idea of a threshold or reversal towards more stabilised rules can be related to three mechanisms that are crucially important for transition dynamics and studied in my thesis: expectations alignment, niche shielding and institutional work.

Expectations play a role as an ex-ante selection environment, which guides both niche and regime actors' activities. As identified in SNM studies, shared expectations are crucial for niche development, since they enable regime and niche actors to invest in the niche. There are three key reasons why this is the case. First, expectations play a role as ex-ante selection environment that makes actors believe in the niche future prospects. Second, when expectations are widely shared among different actors, it can attract other actors too. Third, expectations can generate legitimacy, or more precisely expectations guide actors' activities to create a favourable institutional environment for niche development. Expectations build up a prospective socio-technical structure (Van Lente and Rip, 1998); they set in motion transition dynamics that will lead to two intertwined processes of institutionalisation of the niche and de-institutionalisation or de-stabilisation of the regime.

Niche shielding dynamics are crucial for both the speed and the direction of niche development since niche shielding holds off selection pressures from the dominant socio-technical regime and nurtures niche development (Smith and Raven, 2012). Niche stabilisation requires such a shielding process as regime selection pressure generally leads to regime optimisation. Moreover, active shielding from regime actors can speed up niche development.

According to insights from neo-institutional studies, institutional change is a result of continuous interactions between different actors adopting multiple strategies of institutional work (Lawrence and Suddaby, 2006; Lawrence et al., 2009). For the purposes of this study, I will therefore focus on how niche and regime actors enact this institutional work. I will use institutional work literature since it studies institutional change as a result of collective actions among different actors, including creating, maintaining or disrupting types of institutional work. These three types resonate with the two intertwined processes of niche development and regime destabilisation.

## 1. 5 Theoretical contributions and academic relevance

This section details the academic contributions of this thesis, but first I would like to argue that my thesis provides a general contribution. I conclude this section with observations about relevant audiences.

### 1. 5. 1 A general contribution: bridging the dichotomy between top-down and bottom-up approaches

This thesis regards transition dynamics as being shaped by collective actions among different actors, who are distributed across different socio-technical domains and across multiple scales. Following insights taken from institutional theory, this thesis regards transition dynamics as dependent on the process of how actors collectively shape institutional change. In this sense, it contrasts with the conventional dichotomy of top-down or bottom-up arguments to shape transition dynamics. For example, Yap and Truffer (2019) proposed two streams of literature to identify the core processes of how actors shape the selection environment for industry transformation. The first is a top-down approach through government actions (regime actors) to create directionality. Following the work of Weber and Rohracher (2012) and Mazzucato (2016), they argued that directionality can result from a top-down public policy approach that shapes technological change into desirable directions. The second approach they proposed is the bottom-up approach in which institutional entrepreneurs (niche actors) are involved in institutional work and initiate the change process. In my study, I bridge bottom-up or top-down approaches and regard sustainability transitions as a result of collective actions among heterogeneous actors embedded in different selection environments (niche and regime). A related point is that I do not want to assume that a transition is led by niche actors or that incumbent actors are resistant to transformative change. Both niche and regime actors are heterogeneous, holding different powers, resources, beliefs and interests (Foxon et al., 2010) and they generally offer complementary assets (Farla et al., 2012; Bergek et al., 2013; Berggren et al., 2015; Steen and Weaver, 2017). Both are needed for a transition, and it is the particular alignment between them that may influence the speed and directionality of niche development. Having specified my general conceptual contributions, here I summarise the specific contributions that this thesis makes to existing knowledge. They cover conceptual, methodological and empirical contributions:

- The thesis introduces an original conceptual framework to study the alignment dynamics between niche and regime actors' expectations, and how their alignment shapes niche acceleration. It conceptualises three patterns of alignment: strong, medium-strong and weak alignment (Chapter 3);

- The thesis introduces a quasi-quantitative methodology to measure the above alignment dynamics between niche and regime actors' expectations during the niche development process (Chapter 3);
- The study proposes a 16% adoption rate of niche technology as a threshold for niche acceleration (Chapter 3).
- The thesis develops a previously underdeveloped concept of niche shielding by investigating how niche and regime actors interact to shape niche shielding dynamics from two aspects. The research findings suggest insightful lessons for when and how to phase out temporary protective spaces for radical innovation (Chapter 4);
- The thesis proposes a novel conceptual framework to investigate what types of institutional work niche and regime actors enact to shape the directionality of niche development (i.e. either a fit-and-conform or a stretch-and-transform pattern). It elaborates three key aspects: a portfolio of institutional work (introducing a range of possible distinctions); the nature of niche and regime interactions (whether niche actors play a leading role in shaping institutional change working with regime actors, or regime actors play a leading role, and ignore the disruptive institutional work of niche actors); and the institutional conditions that they can mobilise across multiple scales (Chapter 5);
- The thesis contributes to the geography of sustainability transitions studies by considering the multi-scalar dimension of niche–regime interactions (chapters 4 and 5).
- The study makes significant empirical contributions by analysing the rapid development of wind and solar development in China at both the national and provincial level (with a focus on two provinces: Inner Mongolia and Jiangsu) from 2000 to 2017.
- Moreover, the empirical insights suggest that the rapid wind and solar power development in China cannot be attributed to the national policy and the presence of a strong state but depends on the collective actions among different actors. Especially, the cases indicate that the provincial actors proactively shape institutional change across both provincial and national scale to shape their preferred directions of niche development.

#### 1. 5. 2 Academic audience and debates

This thesis engages primarily with the growing research community in the sustainability transitions field that is interested in long-term socio-technical systems change. Specifically, it

develops understanding of niche acceleration, adding insights to MLP and SNM studies. Moreover, it integrates a spatial dimension into niche studies responding to the recently emerging research agenda on the geography of sustainability transitions.

The thesis also relates to several classical debates in other academic communities. For example, it contributes to the discussion on the role of expectations in the sociology of expectations literature. Moreover, it contributes to discussion on the role of institutional work in the sociological literature on institutional change; and finally, it contributes to the debate on the endogenous and exogenous driving forces for institutional change.

Within the sustainability transitions field there is a growing interest in studies taking a Global South perspective. This study fits in that pattern, although I would like to argue that my results based on a study of China are particularly relevant for a study of big emerging economies with rapid urbanisation and industrialisation (such as India, South Africa and Brazil) that leads to serious concerns of energy security and domestic environmental pollution. In addition, my results may be equally relevant for the Global North, for example for explaining the *Energiewende* (energy transition) in Germany.

## 1.6 Overview of the thesis

This thesis contains six chapters. Three of these chapters (chapters 3–5) have been published or submitted as journal articles. These three chapters form the main body of the thesis. They are supported by:

Chapter 1 (this chapter) which provides the research background and motivation for the research, and it introduces a number of key concepts and definitions of studying socio-technical system innovation towards sustainability. It also specifies the research aims and questions, the theoretical contributions, and the academic audience of this study. Lastly, the coherence of the thesis structure is clarified.

Chapter 2 introduces a process theory understanding of socio-technical change, the methodology used in the thesis and the methods for data collection and analysis.

Chapter 6 provides a discussion of the key findings and contributions from the three key chapters 3–5 and how they address the research questions. It reflects upon the limitations of this study's research findings before it concludes with recommendations of potential avenues for future research.

Chapters 3–5 make their own contributions using different but related concepts. They explore mechanisms of how niche and regime actors interact to shape niche acceleration. I examine two

aspects of this process: its speed and its directionality. Chapter 3 addresses niche acceleration (rapid niche development) while Chapter 5 addresses directionality of niche development. Chapter 4 examines the process of how niche and regime actors shape niche shielding dynamics, which contributes both to the speed and to the directionality of niche development (illustrated in Figure 1.4).

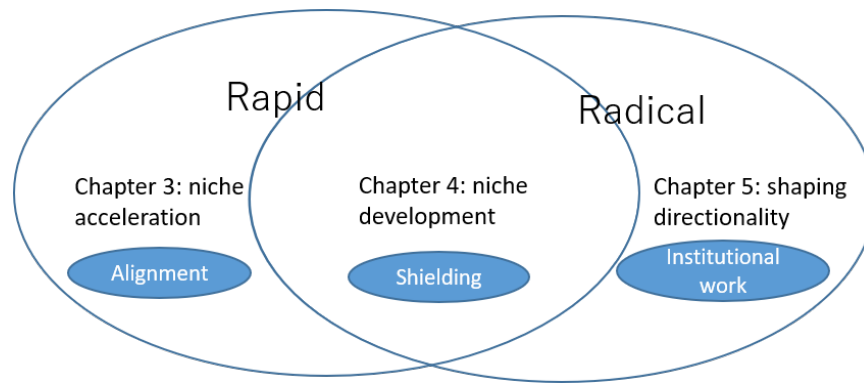


Figure 1.4. Visualisation of the focus areas of the three core chapters

To be more specific: Chapter 3 addresses the research question of how the interaction between niche and regime actors unfolds during the niche development process, and how their interactions shape the speed of niche acceleration. It conceptualises three alignment patterns between niche and regime actors based on their expectations. Furthermore, it develops a novel conceptual framework to explore whether and how these three alignment patterns correlate with three different stages of niche development. It tests the framework through case studies of wind and solar power development between 2000 and 2017 at the national level. It concludes that for both cases one of the three patterns relates strongly with niche acceleration (rapid niche development).

Chapter 4 unpacks how niche and regime actors interact to shape niche shielding dynamics through two aspects:

- 1) How they interact to shape niche shielding across multi-dimensions of the socio-technical system;
- 2) How they interact to shape niche shielding dynamics across multiple scales.

It suggests that niche and regime actors may align in certain dimensions while conflicting in other dimensions across multiple scales. The lack of coordination in these different dimensions across multiple scales constrains the rapid niche development. Moreover, the study argues that although the active shielding enacted by regime actors may contribute to rapid niche development, it constrains the directionality of niche development: it may become less radical.

Chapter 5 traces the process of how actors enact multiple types of institutional work to shape the directionality of niche development. The research findings suggest the nature of alignment between niche and regime actors (i.e. niche actors play a leading role in shaping institutional change when working with regime actors, or regime actors play a leading role and ignore the disruptive institutional work of niche actors) is one of three core aspects to examine the directionality of niche development. This complements the insights from chapters 3 and 4.

The three chapters have their own justifications for case selection. Chapter 3 examines the speed of niche development, focusing on wind and solar power development in China at the national level since the two niche technologies have diffused rapidly across the country over the last two decades. As indicated in its conclusion, China's RE diffusion cannot be exclusively attributed to the national government; provincial actors have been playing proactive roles as well. This is the empirical focus of chapters 4 and 5. To be specific, these two chapters investigate in detail how actors interact to shape wind and solar power development in two provinces, Inner Mongolia and Jiangsu. Chapter 4 illustrates that the state and provincial actors may align their niche shielding strategies in certain dimensions while being in conflict in other dimensions. Chapter 5 also shows evidence that the local actors adopt multiple types of institutional work to shape institutional change across multiple scales (both provincial and national). This finally leads to different directions of socio-technical change for their preferred corresponding solar PV integrated energy systems: centralised in Inner Mongolia and decentralised in Jiangsu. Overall, the empirical insights enrich the understanding of China's RE diffusion at the national level and within two specific provinces. They account for how different actors interact to shape the system transformation of China's electricity system towards wind and solar power development.

In summary, the consistency of the thesis is rooted in exploring how the interactions between niche and regime actors have shaped the development of solar and wind power in China. The characteristics of chapters 3–5 are further summarised in Table 1.2.

Table 1.2. Summary of the three core chapters

	<b>Chapter 3 (Article 1)</b>	<b>Chapter 4 (Article 2)</b>	<b>Chapter 5 (Article 3)</b>
<b>Title</b>	<i>Expectation dynamics and niche acceleration in China's wind and solar power development</i>	<i>Niche shielding dynamics: Patterns of wind power development in two Chinese provinces</i>	<i>Shaping the directionality of sustainability transitions: The diverging development patterns of solar PV in two Chinese provinces</i>
<b>Aim of research</b>	Understand how the alignment dynamics between niche and regime	Unpack how niche and regime actors interact to shape niche shielding	Understand how niche and regime actors



	actors' expectations shape niche acceleration	dynamics from two aspects: multiple dimensions and multiple scales	shape directions of niche development
<b>Research question</b>	How do the alignment dynamics between niche and regime actors unfold during the niche development process? In particular, how does their alignment shape the acceleration of niche development?	How do niche and regime actors interact to shape niche shielding dynamics?	What types of institutional works do niche and regime actors enact to shape directions of sustainability transitions?
<b>Literature</b>	Multi-level perspective; Social dynamics of expectations	Strategic niche management; Geography of sustainability transitions	Institutional work; Geography of sustainability transitions
<b>Main concepts</b>	Expectations; Alignment patterns	Shielding	Institutional work; Institutional pillars
<b>Case study</b>	Wind and solar power development in China (2000–2017)	Wind power development in Inner Mongolia and Jiangsu (2000–2017)	Solar power development in Inner Mongolia and Jiangsu (2000–2018)
<b>Contribution</b>	Develops a novel conceptual framework; Conceptualises three different alignment patterns between niche and regime actors; Offers threshold to measure different stages of niche development; Offers a novel quasi-quantitative methodology to map different types of alignment	Offers a conceptual framework; Discovers that niche and regime actors may align in certain dimensions while conflict in other dimensions across multiple scales; Contests niche construction as a linear process of phasing out protective spaces step-by-step	Develops the concept of multi-scalar institutional work; Opens the black box of institutional change; Formulates four propositions to understand how niche and regime actors enact different types of institutional work to shape directions of sustainability transitions; Develops a novel conceptual framework
<b>Dissemination</b>	Presented at the IST conference 2019; Published in the SPRU Working Paper Series; Published in <i>Environmental Innovation and Societal Transitions</i>	Presented at SPRU Wednesday seminar, March 2019; Presented at the STRN conference (Lisbon, April 2019); Presented at the EU-SPRI early career writing forum (June 2020);	Present at the IST conference 2020; Published in the SPRU Working Paper Series; Accepted by <i>Regional Studies</i>

		Under revision at <i>Energy Research and Social Science</i>	
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I now clarify my contributions to each of the three chapters that have been written as articles. Chapters 3 and 5 are based on a co-authored article of which I was the lead author, while Chapter 4 is based on a solo authored article (described in Table 1.3).

Chapter 3 (Article 1) titled “Expectation dynamics and niche acceleration in China’s wind and solar power development” is co-authored with my two supervisors. The research question, research design and research framework have emerged through discussion with my two supervisors. Interview questions were designed by me but discussed with and adjusted by my supervisors. I conducted all the interviews, while the workshop that also informed the article involved all three authors. The data analysis was discussed between all three authors, led by me. I provided a first draft of the article, which then led to an intense process of revisions before submission to a journal. The article was revised following peer review. Revisions involved all authors but were led by me.

Chapter 4 (Article 2) titled “Niche shielding dynamics: patterns of wind power development in two Chinese provinces” is a solo-authored paper by me. The work was guided by my supervisors, in particular Dr Ralitsa Hiteva. However, I conducted the whole process of research, including research design, literature review, research framework, data collection and analysis, and writing.

Chapter 5 (Article 3) titled “Shaping the directionality of sustainability transitions: The diverging development patterns of solar PV in two Chinese provinces” is a paper co-authored with Professor Johan Schot, one of my supervisors, and Professor Bernhard Truffer who hosted me at Utrecht University during a research visit. The two co-authors were involved in the framing of the article, but I was responsible for providing a first draft based on my research. This draft was revised in several rounds with substantial inputs from my two co-authors, in a process led by me.

Table 1.3. Declaration of contribution by PhD candidate to the three journal articles

Articles	Research design	Literature review	Research framework	Data collection and analysis	Writing	Revision
Article 1 (Chapter 3): Expectation dynamics and niche acceleration of China’s wind and solar power development	√	√	√	√	√	√

Kejia Yang, Ralitsa Hiteva, Johan Schot; Published in <i>Environmental Innovation and Societal Transitions</i>						
Article 2 (Chapter 4): Niche shielding dynamics: patterns of wind power development in two Chinese provinces Kejia Yang Under revision at <i>Energy Research and Social Science</i>	√	√	√	√	√	N/A
Article 3 (Chapter 5): Shaping the directionality of sustainability transitions: The diverging development patterns of solar PV in two Chinese provinces Kejia Yang, Johan Schot, Bernhard Truffer Accepted by <i>Regional Studies</i>	√	√	√	√	√	N/A

√ indicates my contributions to a specific task in-depth

N/A indicates not applicable. This refers to revisions resulting from journal reviews. For article 3 some revisions were made as a result of comments received from SPRU colleagues who reviewed the paper for the SPRU Working Paper series.

## Chapter 2 Research design and methodology

### 2. 1 Process theory of socio-technical change

This thesis adopts process theory to examine the causality of long-term socio-technical system change. That is to say, this study seeks patterns and underlying mechanisms instead of statistical causal effect. Rather than seeking causal variables, it examines events. Process theory regards change outcomes as results of temporary sequences of historical events (Mohr, 1982; Langley, 1999). These events are enacted by actors who make decisions and react to others' actions (Poole et al., 2000). The social reality happens in sequences of actions located within constraining or enabling structures (Abbott, 1992). Timing and conjunctures of event chains construct the narrative causality (Pentland, 1999). In this sense, to unpack the complex socio-technical system change, this thesis relies on event sequences and conjunctures across multiple dimensions, layers and scales that occur through interactions between actors and which construct the narrative causality. Compared with variance theory, which explains change outcomes as an accumulated result of independent variables, process theory is regarded as appropriate to examine complex and long-term system changes, and it has been widely adopted in sustainability transitions studies (Geels and Schot, 2010). Readers can refer to Langley (1999) for explanations of differences between process theory and variance theory to explain historical processes. The narrative causality was regarded as appropriate for the purpose of this study as it allowed me to trace the long-term transformative change of the socio-technical system to observe how niche and regime actors interact, and to investigate under what conditions the two interact to shape niche acceleration.

### 2. 2 Case study research design

This research adopts a case study approach which is considered appropriate given this study needs to develop an in-depth understanding of "how" and "why" certain patterns or underlying mechanisms unfold during the transition process. Case studies offer rich context knowledge that enables the researchers to identify internal and external interventions that might be responsible for the research findings (George and Bennett, 2004; Yin, 2014). As pointed out by Eisenhardt (1989): "When a relationship is supported, the qualitative data often provide a good understanding of the dynamics underlying the relationship, that is, the 'why' of what is happening. This is crucial to the establishment of internal validity [to sharpen the hypothesis]" (p. 542). This thesis specifically aims to explore and investigate through which mechanisms niche and regime actors interact and how their interactions shape niche acceleration. In this context, qualitative data are particularly useful for understanding how the processes unfold and why. As

pointed out by Geels and Schot (2010): “Transitions are processes that unfold over time, involving structural change and non-linearities. Investigations of this kind of phenomenon require a research method that is rich in context and tracks complex developments over time” (p. 99). Longitudinal case studies allow detailed process tracing (study of event sequences) to explore and investigate underlying changing patterns and uncover underlying generative mechanisms that deepen understanding of the studied phenomenon. They have become a dominant approach adopted by transition studies (Zolfagharian et al., 2019). Therefore, to trace processes of change over an extended period of time, this thesis adopts longitudinal cases.

Overall, this thesis aims to develop and test theory by using case studies. The theory concerns how niche and regime actors interact to shape niche acceleration. Replication logic is central for my case study strategy (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). This means that each case is treated as independent and analogous to an experiment, and multiple cases are adopted that serve as replications, contrasts and extensions to the emerging theory (Eisenhardt and Graebner, 2007; Yin, 2014). This offers foundations for generalisation of research findings beyond the specific cases, socio-technical systems and countries that the study chooses (Yin, 2014). In this thesis, all three core chapters adopt multiple independent cases following this replication logic. Moreover, the adopted longitudinal cases allow all three chapters to search and discover patterns within and across cases as suggested by Yin (2014).

To answer my overall research question of how niche and regime actors interact to shape the niche acceleration, three individual questions were developed and addressed in the three core chapters. To build up internal validity, the research design is iterative, with research questions, conceptual framework, methodology and analysis built reflectively throughout the whole research project. In other words, each chapter generates insights for subsequent following studies. Table 2.2 presents the overall research design of the three core chapters.

Having justified why this thesis adopts a case study approach, here I will explain my strategies to select cases for each chapter. Each chapter addresses one of the three sub-questions and thus employs different cases for different aims, albeit they all follow the same paradigmatic strategies of case selections proposed by Flyvbjerg (2006). Together they seek to answer the main research question.

Chapter 3 addresses the research question of how alignment patterns between niche and regime actors unfold and how their alignment dynamics shape niche acceleration. Based on the selective literature review, expectations have been identified as key for niche and regime actors to build alignment. Therefore, the chapter investigates to what extent expectations play a crucial

role for shaping alignment dynamics between niche and regime actors for the purpose of niche acceleration. Selected cases should allow me to test whether proposed changing expectation alignments (based on the selective literature review) do indeed evolve with niche developments. The chapter selected two longitudinal cases of wind and solar power development at national level from 2000 to 2017. The period from 2000 to 2017 was selected because it covers different stages of niche development. The two niche technologies were barely existent in the country around the turn of the century, while by the end of the studied period (2017), China was leading in both areas, and the niches were contributing 5% and 3% to the country's generation mix respectively.

Chapter 4 addresses the question of how niche and regime actors interact to shape niche shielding dynamics. Therefore, cases selected for investigation should offer contrasting niche shielding dynamics to allow me to explore the proposed conceptual framework which examines niche shielding across multiple dimensions and multiple scales. It selected two contrasting cases: wind power development in two provinces, Inner Mongolia and Jiangsu province, where divergent niche development patterns have been observed. I choose to focus on wind power because it is more established than solar power, so it might be expected to bring out richer insights of shielding practices. The two provinces, Inner Mongolia and Jiangsu, were selected as they present contrasting wind power development patterns. Inner Mongolia is leading in the country's wind power installed capacity, although it has strong regime players in place for its strategy, which aims to export its clean power to other provinces. In contrast, Jiangsu province witnessed more moderate wind power development, although it could rely on natural shielding coming from a substantial provincial electricity demand which is lacking in Inner Mongolia.

Chapter 5 addresses the research question of how various types of institutional work enacted by niche and regime actors shapes the directions of sustainability transitions. Since only a few studies offer useful insights for this research question, the chapter explores a number of relevant dimensions of institutional work identified in the literature. It seeks cases that can offer insights with diverging directions (fit-and-conform and stretch-and-transform pattern) in order to explore whether identified dimensions of institutional work have been instrumental in putting in place the directionality embedded in the specific pattern. This leads me to select two contrasting cases: solar power development in two provinces of Inner Mongolia and Jiangsu. Solar PV development in Inner Mongolia is dominated by large-scale power plants fitting into its existing centralised power plants (i.e. fit-and-conform pattern), while Jiangsu province has developed a distributed solar PV system that has started to transform its centralised power system (i.e. stretch-and-transform pattern). The selection of solar PV development as the case

is more appropriate because it has shown divergent niche development directions compared with wind power, which is dominated by large-scale power plants fitting into the country's existing centralised power system.

In all three chapters, whether I test a framework, or explore a conceptual framework, I have been following a comparative case study strategy looking for similar or contrasting patterns between the cases. The cases I use for each chapter are studied from different angles: expectation alignment, niche shielding, and institutional work. The three angles together provide an answer to my main research question: how did the interactions between niche and regime actors shape wind and solar power niche acceleration in China's electricity socio-technical system in the period of 2000–2017. Rather than providing a comprehensive answer, these three angles address three crucial areas on how niche–regime interactions are shaping niche acceleration.

While each chapter has its own case study logic, I would like to argue that my choice of China as a case study for the overall thesis is an example of “maximise variation” logic, as suggested by Flyvbjerg (2006) :

When the objective is to achieve the greatest possible amount of information on a given problem or phenomenon, a representative case or a random sample may not be the most appropriate strategy. This is because the typical or average case is often not the richest in information. Atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied (Flyvbjerg 2006, p. 229).

China is an extreme case because of its fast niche acceleration, unprecedented in the world. I focus on wind and solar power development in China, both at the national level and in two specific provinces, Inner Mongolia and Jiangsu. The two niche technologies, wind and solar power, are selected as they have challenged the current coal power-dominated regime in China's electricity socio-technical system. The diffusion of these two niche technologies require a change not only of technology, but also of dispatching practices (from controlling and planning oriented towards RE-prioritised, flexible dispatching practices), market rules (from fossil fuel friendly to RE friendly market), industry (from coal power industry towards RE industry), culture and social values (from previous singular economic growth goal towards more diverse societal goals embracing clean and low carbon values). Therefore, the two technologies feature the characteristics of socio-technical system transformation and clearly identified niche and regime actors, which fits the purpose of this study.

## 2. 3 Data collection and analysis

All three core chapters adopt a longitudinal case study approach. Hence data collection covers historical events, the role of actors and changes of institutions over a longer period (2000–2017). The choice of long-term historical data collection allows me to observe trends and turning points and a host of key events. These historical events provide the backbone for the development of narrative explanations of the case studies, which finally leads me to identify general patterns of niche and regime actors' alignment and the underlying mechanisms of how they shape niche acceleration.

To improve the data reliability, the thesis adopts multiple data collection methods so that it can collect rich evidence from different approaches for the purpose of complementarity or triangulation. The multiple data collection approaches include: (i) 53 semi-structured interviews; (ii) a workshop with 22 participants representing niche and regime actors from national and provincial level; (iii) desk-based research; (iv) informal interviews; (v) conference observation; and (vi) focus groups.

Primary data collected through 53 semi-structured interviews included 47 face-to-face interviews, 4 telephone interviews and 2 Skype calls (see Appendix Table A.1). Interviews were preferably held in person, but telephone or Skype were chosen as a second choice when travelling was not feasible, for example, because it was too costly in terms of time and money. The interviews were conducted in two rounds, between July 2017 and March 2018 and between December 2018 and January 2019. The second round enabled me to check information collected from the previous round and to collect more information to investigate in depth the identified pattern or phenomenon in the first round. The respondents covered different stakeholders which had been identified as relevant to shaping wind and solar power development at the national level and/or provincial level. All semi-structured interviews lasted for around 1 hour. Most were conducted in Mandarin, were audiotaped and then transcribed and translated into English. My positionality as a Chinese, familiar with the culture and context of the country, helped me to interpret the collected data, sometimes to gauge the real meaning behind participants' words and to translate the language from Mandarin to English without losing the original meaning and nuances of the narrative.

To complement the interview data, which might be biased considering the retrospective nature of the study, I adopted different strategies such as triangulating multiple data resources, approaching different stakeholders to guarantee diversity in terms of data value, and cross-checking data from different stakeholders. To improve interview data credibility, I also used



different approaches to identify the key stakeholders. For example, as well as using snowballing, I also used institutional mapping and attending conferences to identify key stakeholders relevant to the studied socio-technical change. Moreover, six informal chats were conducted to test and access sensitive data, such as the expectations of the coal power regime. Several conferences were attended to observe different stakeholders' perceptions, and to identify and approach appropriate interviewees. Relevant materials, such as slides presentations and organisational reports, were accessed through attending these conferences. Secondary data were selected, including journal articles, policy documents, organisational reports and news articles to identify relevant information or to enable triangulation of interview data (depicted in Table 2.1).

Furthermore, a workshop was conducted in March 2018 in Beijing, at the end of the first round of fieldwork (see Appendix Table A.3). It served the purpose of triangulating data collected up to that point, testing different stakeholders' perceptions. During the workshop, 22 stakeholders were invited to reflect on the detailed storylines of key institutional changes and historical events of wind and solar power development at the national and provincial level based on the data collected from interviews and desk-top research. Data were collected through different formats during the workshop, including presentations, focus groups and plenary discussions. Apart from serving the purpose of triangulation and building consensus across different stakeholders, new insights were also generated from the workshop, especially regarding the specific role of different stakeholders. For example, the proactive role of local actors became obvious in explaining the diverging development patterns of solar PV in the two provinces, which served as the foundation for the second round of fieldwork.

In the second round of fieldwork, data were collected mainly for the purpose of investigating the provincial actors' types of institutional work to shape the directionality of solar PV development. To elaborate, 11 new semi-structured interviews were conducted, and 4 follow-ups to triangulate certain information collected from the first round and to collect some new data. In addition, 4 focus groups were conducted to gain a shared understanding of certain actors' activities and cognitive beliefs (see Appendix Table A.2). These focus groups included 12 people in total and lasted for around 2 hours. The collected data was mainly used to inform Chapter 5.

Table 2.1. Secondary data sources

	<b>Data Source</b>
<b>Journals</b>	Database of journal articles using keyword searches: "solar power" "wind power" "Grid" "low-carbon" in Chinese and English in the database of CNKI & Webofscience,

	and drawing on the Chinese professional journals <Wind Power> <sup>3</sup> , <Solar Energy> <sup>4</sup> ; <State Grid> <sup>5</sup>
<b>Policy &amp; organisation documents</b>	Central and local government policy documents, such as renewable energy development plans; Industry associations; organisation reports, such as the annual reports by the China Electricity Council from 2001 to 2017; investment data from organizations' official websites; Other statistical data from NEA, Electric Power Association; Industry reports: such as Electric Power Industry Development Annual Report <sup>6</sup> , produced by the China Electricity Council; Some of government consultancy reports, such as Energy Development
<b>News</b>	BJX-professional news website covering all electric power news; China Power News Network; Electric Power development; China Electric Power News; China Energy News

To interpret the collected data, I used pattern matching and cross-case comparisons as two key analytical strategies for case analysis (Yin, 2014). Pattern matching was adopted to examine matches and mismatches of the conceptual and empirical insights. A “good match” means that the empirical insights confirmed the conceptual understandings and the proposed causal mechanisms. Moreover, the multiple cases allow cross-case comparisons to identify either similar or contrasting patterns across cases. This is a useful analytical strategy to explore, test and generate theory. To elaborate, Chapter 3 tests the theoretical framework using both pattern matching and cross-case comparisons, while chapters 4 and 5 adopt cross-case comparisons to explore and develop a theoretical framework. In Chapter 3, both wind and solar cases follow similar patterns of strong alignment between niche and regime actors during niche acceleration stage. In chapters 4 and 5, there are contrasting patterns observed in the two cases.

To serve different purposes of data analysis, different chapters adopt different coding approaches. Chapter 3 adopts a thematic coding approach following the developed conceptual framework. Chapter 4 adopts open coding following the approach introduced by Blair (2015) in order to capture more empirical insights that go beyond the original theory. The insights that emerged from this process complemented the theoretical concepts and fit the purpose of explorative nature of the chapter. Chapter 5 first adopts open coding to identify the multiple aspects of institutional work, followed by thematic coding to code actors' key work activities (institutional work).

Table 2.2. Overall research design for chapters 3–5

	<b>Chapter 3</b>	<b>Chapter 4</b>	<b>Chapter 5</b>
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<sup>3</sup> The journal was first published in 2005, thus the data reviewed was from 2005 until 2017.

<sup>4</sup> Data reviewed was from 2000 to 2017.

<sup>5</sup> The journal was first published in 2006, thus the data reviewed was from 2006 until 2017.

<sup>6</sup> From 2000 to 2017.

<b>Aim</b>	Test theoretical framework	Concept developing	Developing theoretical framework
<b>Research question</b>	How do the alignment dynamics between niche and regime actors unfold during the niche development process? In particular, how does their alignment shape the acceleration of niche development?	How do niche and regime actors interact to shape niche shielding dynamics?	What types of institutional work do niche and regime actors enact to shape directions of sustainability transitions?
<b>Focal point of transition dynamics</b>	Niche acceleration (speed of niche development)	Speed and directions of niche development	Directions of niche development
<b>Methodology</b>	Comparative case studies; Following replication logic design	Comparative case studies; Following replication logic design	Comparative case studies; Following replication logic design
<b>Strategies for case selection</b>	Paradigmatic cases	Paradigmatic cases	Paradigmatic cases
<b>Cases selected</b>	Wind and solar power at the national level	Wind power development in Inner Mongolia and Jiangsu province, and national development	Solar PV development in Inner Mongolia and Jiangsu province and national development
<b>Data sources</b>	Secondary data; 31 semi-structured interviews; Informal chats; Workshop	Secondary data; Two rounds of fieldwork; 30 semi-structured interviews; Workshop	Secondary data; Two rounds of fieldwork; 42 semi-structured interviews; Workshop; Focus group
<b>Analytical strategy</b>	Pattern matching & cross-case comparison	Cross-case comparison	Cross-case comparison
<b>Coding approach</b>	Thematic coding following the developed conceptual framework	Open coding to identify the shielding dynamics (Blair, 2015)	Open coding to first identify key factors, and then follow thematic coding to code actors' key activities (institutional work)

## Chapter 3 Article 1

### **Expectation dynamics and niche acceleration in China's wind and solar power development**

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## Abstract

This paper addresses the question of how alignment dynamics between niche and regime actors shape niche acceleration. We develop a conceptual framework that focuses on the role of expectations as a necessary precondition and even as a key proxy for strategic collaboration between niche and regime actors. Based on actors' expectations, we conceptualise three alignment patterns of strong, medium-strong and weak alignment. We propose a 16% threshold of niche technology adoption for substantial niche acceleration. We explore our conceptual framework in two contrasting case studies of wind and solar power development in China between 2000 and 2017. Both cases experienced niche acceleration but followed different paths. Our research findings indicate that the three proposed alignment patterns between niche and regime actors' expectations can be seen as a good proxy for explaining these different paths. Strong alignment between niche and regime actors' expectations does go hand in hand with niche acceleration.

**Keywords:** Niche acceleration; Expectations; China; Wind power; Solar power

## Highlights:

- Investigates how the alignment dynamics between niche and regime actors unfold for niche acceleration;
- Conceptualises three alignment patterns between niche and regime actors' expectations;
- Develops a conceptual framework which matches three alignment patterns between niche and regime actors' expectations with three niche development phases including substantial niche acceleration;
- Traces alignment dynamics between niche and regime actors' expectations for wind and solar power development in China between 2000 and 2017;
- Concludes that strong alignment between niche and regime actors' expectations can accelerate niche development.

### 3. 1 Introduction

This paper addresses the question of how alignment dynamics between niche and regime actors shape niche acceleration. From the literature it is clear that in the acceleration phase of niche development, not only niche actors but also regime actors play an important role (Hoogma et al., 2002; Elzen et al., 2012a; Geels et al., 2012; Späth et al., 2016). Niche actors need political power, finance and other resources to help niches stabilise or grow. They generally achieve this through collaboration with regime actors, who are powerful actors usually in possession of complementary assets (Tripsas, 1997; Rothaermel, 2001a; Dyerson and Pilkington, 2005; Rothaermel and Hill, 2005; Steen and Weaver, 2017). However, niche and regime actors have been characterised as embedded in different socio-technical selection environments and unlikely to build strategic collaborations to create a competitive niche (Jacobsson and Bergek, 2004; Smink et al., 2015a; Smink et al., 2015b). Under what conditions, then, can niche and regime actors build alignment which can contribute to niche acceleration?

Strategic collaboration between niche and regime actors can take many forms (Rothaermel, 2001b; Stenzel and Frenzel, 2008; Elzen et al., 2012a; Farla et al., 2012; Bergek et al., 2013; Steen and Weaver, 2017; Apajalahti et al., 2018; Kungl and Geels, 2018; van Mossel et al., 2018). This paper focuses on the role of expectations as a necessary precondition and, in fact, key proxy for a strategic collaboration between niche and regime actors. Our proposition is that strategic collaborations between niche and regime actors with the aim of niche acceleration are unlikely to occur until the two share specific expectations. The crucial role of expectations for forging collective actions among actors is widely recognised in the literatures of both sociology of expectations and sustainability transitions (Brown et al., 2003; Berkhout, 2006; Konrad, 2006; Schot and Geels, 2008; Budde et al., 2012; Budde, 2015). Expectations can generate ex-ante selection pressures. They define a future selection environment in which actors need to operate. If actors assess that they are not fully equipped to act in that future, they may invest in new directions (niches) even though they can compete in current selection environments (Van Lente and Rip, 1998; Geels and Smit, 2000; Borup et al., 2006; Van Lente and Bakker, 2010). Actors invest in niche development based on their expectations that the niche may become the regime of the future (Van Lente and Rip, 1998). Moreover, the articulation of expectations helps to enrol other actors and could be a key way for niche actors to expand their social network and to build internal momentum for niche acceleration (Schot, 1998; Schot and Geels, 2008).

To answer our research question, we develop a quasi-quantitative mapping tool to systematically capture different types of alignment between niche and regime actors. We categorise them into three basic alignment patterns: *weak*, *medium-strong* and *strong*. Based

on technology diffusion studies we propose different thresholds to categorise three niche acceleration phases: slow niche development, moderate niche development and substantial niche acceleration. Building on these, we develop a conceptual framework to examine how these three alignment patterns correlate with three different stages of niche acceleration.

We explore the robustness of the framework with two longitudinal case studies of wind and solar power development in China between 2000 and 2017, allowing a systematic comparison. We use the case studies for theoretical generalisation or sampling (George and Bennett, 2004; Eisenhardt and Graebner, 2007; Yin, 2014). In other words, we use the empirical analysis to sharpen our ideas and develop the framework. As indicated in Figure 3.1, the period in focus covers all development stages of two niches. In 2000, both were virtually non-existent in China, while by 2017, wind and solar had grown to 12.4% and 42.46% respectively of the national new installed market (see Figure 3.5). Both cases are suitable for developing the framework not only because wind and solar power have taken off rapidly but also because they followed different trajectories we can usefully compare. We can thus observe niche acceleration in different time periods within the same context (China) and explore whether we can relate these periods within and across both cases to our projected expectation alignment patterns between niche and regime actors. We acknowledge that China may be a specific case, because both types of actors may have a particular relationship due to the specific role of the state in the country. This issue will be discussed in the final part of the paper.

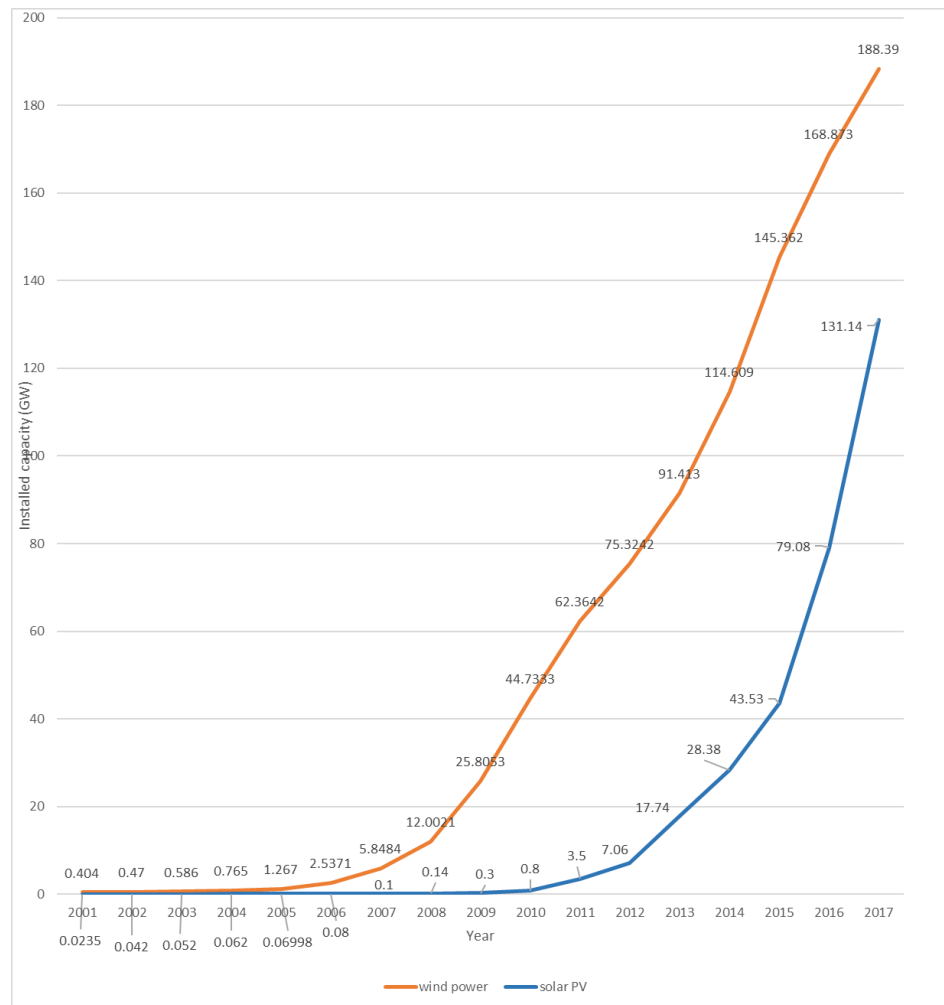


Figure 3.1. Historical development of installed capacity of wind and solar power in China (2001–2017).

Source: Author's own, wind power based on statistical data from the Chinese Wind Industry Association (CWEA)<sup>7</sup> and Wang et al. (2012); solar power capacity from data provided by International Energy Agency (IEA).

The paper is structured as follows. Section 2 introduces the concepts of expectations and alignment building in sustainability transition and sociological studies of expectations literature, followed by the introduction of the three conceptualised alignment patterns, and a definition of three niche acceleration phases. Section 3 introduces the operationalisation and methodology. Some of the key aspects of the framework need contextualisation. For example, to apply our conceptual framework, we have to specify who niche and regime actors are and define the phases of niche acceleration in the two cases. We then present how we organised the data-gathering process. Section 4 presents a historical and comparative account of alignment patterns between niche and regime actors' expectations in relation to the niche acceleration phases. Section 5 provides a discussion of the results. Section 6 offers concluding remarks.

<sup>7</sup>Note: generally, CWEA data are higher than NEA data because NEA data cover grid-connected installed capacity, while CWEA data refer to wind turbines that have been installed but may not be connected to the grid.



### 3. 2 Aligning expectations in sustainability transitions

#### 3. 2. 1 Alignment between niche and regime actors through expectations

The sociology of expectations and sustainability transitions literatures recognise expectations as playing an essential role in guiding the emergence of new technologies and niches. When niche innovations emerge, actors generally hold various and often contradictory visions of the future (Garud and Ahlstrom, 1997; Rip and Talma, 1998; Van Lente and Bakker, 2010). This is especially true for niche (new entrants) and regime (incumbent) actors. When niche and regime actors' expectations become aligned, they begin to drive socio-technical system change in new directions. Van Lente and Rip (1998) argue that these expectations serve as prospective socio-technical structures for actors.

Konrad (2006) argues similarly that widely shared expectations become a social repertoire for a specific community and the public in general. Such a repertoire has force and helps to build a shared agenda for further actions. Furthermore, the collective expectations tend to attract other actors, who do not necessarily share the expectations, to expand the social network. In this sense, expectations could be seen as strategies deployed by the actors to enrol other actors. In his seminal work on the role of expectations, Van Lente (1993) introduces a promise-requirement cycle to explain the performative power of expectation sharing. In such a cycle, promises (expectations) are translated into requirements for socio-technical change.

How do we know whether expectations are shared or aligned? Based on strategic niche management (SNM) literature we propose two dimensions to measure alignment between niche and regime actors (Schot and Geels, 2008). First, the *breadth* of alignment, i.e. how many niche and regime actors are aligned. When expectations are more widely shared, it is more likely they will be translated into actors' shared goals and collective activities. Second, the *depth* of alignment, which relates to what is called in the SNM literature "the quality and specificity" of the shared expectations (Schot and Geels, 2008). We operationalise this dimension by mobilising a multi-level perspective (MLP) understanding of expectations, building upon the work of Truffer et al. (2008) and other scholars in sociological studies of expectations and sustainability transitions literature.

Van Lente (1993) distinguishes three different levels of expectations: micro, meso and macro. For him, micro-level expectations refer to the specification of the artefacts, systems or process to be developed. They function as heuristics and guide the search processes. Meso-level expectations are less specific. They tend to express functions that the technology presumably will fulfil. Macro-level expectations are broad and general. They take the form of scenarios about the technology as a whole to fit societal trends and provide legitimacy for technology

development. This distinction is similar to the three levels identified by Geels and Raven (2006): project-specific expectations, technology field perspective and societal developments. Ruef and Markard (2010) and Van Lente et al. (2013) indicate that expectations at the three levels follow different hype–disappointment patterns. This implies that the nature of actors’ expectations (positive or negative) may be different at the three levels. Budde et al. (2012) illustrate this in their case study of Germany’s mobility systems. Although actors had positive expectations about hydrogen and fuel cell niche technologies, the German government anticipated less positive landscape-level development. This led to a reduction in investment in these technologies. This case illustrates that it is crucial to measure the nature of actors’ expectations across different levels to understand their strategies. Kriechbaum et al. (2018) elaborate on how these multi-level natures of expectations contribute to the divergent niche development of solar PV in Germany and Spain. Their analysis confirms that it is useful to unpack the interaction dynamics across three levels to understand niche development.

The above studies mainly articulate the expectations of emerging technologies, niches and socio-technical structures, while neglecting expectations about regime resilience. Drawing on MLP, Truffer et al. (2008) suggest actors’ expectation structures for system transformation could be mapped in accordance with MLP levels: niche, regime and landscape. They argue actors’ strategies and activities are influenced by their expectations not only about the emergence of niches and landscape-level development but also about regime resilience. Moreover, in their analysis, they distinguished individual actors’ expectations and collective expectations at each level. The prospective socio-technical structure is shaped by actors’ collective expectations at the three levels. Budde and Konrad (2019) suggest that these three levels of expectations may support and reinforce, or contradict and weaken each other, with direct impact on the transition dynamics. In their analysis, Budde and Konrad (2019) expand the focus of actors beyond the conventional research, industry and social actors to include policy actors’ expectation dynamics. They prove that policy also responds to the changing expectation dynamics at three levels. Building on these findings from the literature we can construct a theoretical framework for alignment dynamics between niche and regime actors’ expectations that includes a notion of breadth as well as depth of alignment.

### 3. 2. 2 Typology of alignment dynamics between niche and regime actors’ expectations

Alignment is not a 0/1 dichotomy; in reality there is a wide spectrum between no alignment and complete alignment, and actors may change position over time. We argue that the alignment between niche and regime actors is a dynamic process with shifts along this spectrum. However, how can we measure this dynamic? In this section we develop a theoretical framework that

contains a typology of three basic alignment patterns. To get there, we have to take a number of steps that we will explain in detail in order to make the framework credible. The steps themselves are complex, but they lead to simple end-results: three basic alignment patterns. All building blocks are based on existing literature. Our contribution is the specific way we put them together.

We first recognise that both niche and regime actors are heterogeneous. As indicated by Geels and Schot (2007), regimes are often semi-coherent, not all regime dimensions are fully aligned and they carry internal tensions and contradictions. These tensions could be utilised by niche actors to build connections and to provide windows of opportunity for niche empowerment (Smith and Raven, 2012; Bui et al., 2016). When confronted with pressure or crisis, regime actors perceive different opportunities and hold a variety of expectations about niche, regime and landscape developments (Smith, 2007). Similarly, niche actors may have different expectations about options for niche development and the obduracy of the prevailing regime and landscape developments. The heterogeneity of both niche and regime actors and their expectations generate multiple options for alignment between niche and regime actors.

In order to map all possible options, we have built a typology of alignment patterns between niche and regime actors' expectations in three steps: Step 1: identification of expectations at three different levels. We argue that if the expectations of both niche and regime actors converge for all three levels, there is an in-depth alignment. Step 2: measuring breadth of alignment between niche and regime actors at each separate level. In Step 3 we systematically combine steps 1 (depth of alignment) and 2 (breadth of alignment) in 27 theoretically possible different types of alignment between niche and regime actors' expectations. We then show that these 27 types can be reduced to 12 basic types.

### **Step 1. Distinguish actors' expectations for future developments at three levels**

Following Truffer et al. (2008) and Budde and Konrad (2019) we distinguish between three levels of expectations by both niche and regime actors:<sup>8</sup>

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<sup>8</sup> Our definition differs from Truffer et al.'s (2008). Their definition of collective expectation at the niche level focuses on sectoral or national priorities in innovation policy to support promising technologies. We expand their scope to expectations about emerging socio-technical structures, which include policy, industry, market, technology performance and user behaviours. Our interpretation of the three levels is also different from Budde and Konrad's (2019). For example, they interpret expectations of fossil fuel prices as landscape level, while we argue that this is regime level – which covers different elements of the dominated socio-technical system (including the industry dimension – supply and demand side; see Table 3.1 for specification). They define the proportion of renewable energy in the system as regime-level expectations, but we define that as niche level. See their definition of three levels of expectations on p. 1101.

*Landscape-level expectations:* these refer to actors' perceived future of the external environment, such as perceptions of climate change or environmental issues, which influences the long-term development of the sector or system. These provide external momentum to guide the direction of transition. Landscape-level expectations tend to be more general compared to the other two levels.

*Regime-level expectations:* these are expectations of the regime's incapability of adapting to internal tensions and crises or to external pressures. If regime-level expectations become positive, i.e. actors start to question regime resilience, it will lead to regime destabilisation and thus may contribute to niche development. Expectations of regime incapability cover all dimensions of the dominant socio-technical system. For example, for our case study it includes technology performance of thermal power, its policy support and market environment.

*Niche-level expectations:* these are expectations of future performance of the specific socio-technical configurations of emerging technologies, such as the role of wind power in meeting energy demand, technology performance or expected market competitive advantages. When positive, they will contribute to niche acceleration. Expectation at this level is often more specific, and visible, compared to the other two levels' expectations, as niche actors generally mobilise their expectations and express them as strategies to attract other actors.

## **Step 2. Define breadth of alignment between actors' expectations at each level**

For a transition to happen, niche and regime actors need to align their expectations at each separate level. In other words, transitions require coordination of niche and regime actors' expectations at the landscape, regime and niche levels. We thus measure alignment for each of the three levels separately.

In our proposed theoretical framework, breadth of alignment is defined by three types of alignment between niche and regime actors: (1) *sparse alignment*, towards the end of the spectrum where no regime actors align with niche actors; (2) *broad alignment*, towards the spectrum end where all of the regime actors align with niche actors; (3) *selective alignment*, where some regime actors align with niche actors, an intermediate state between sparse and broad alignment. We thus propose to measure the three degrees of breadth by counting how many regime actors align with niche actors in terms of their expectations at a specific level.

To measure and define selective alignment we need to know what number constitutes 'some' actors. But as this depends on the context and structure of the socio-technical system under study, the framework does not provide an absolute rule on how many regime and niche actors need to align; this needs to be defined for each case study, as we do below.

We are now able to define breadth of alignment between niche and regime actors' expectations at each of the three levels.

*1) Breadth of alignment between actors' expectations at landscape level*

When regime actors begin to share the perception that changes at the landscape level challenge future regime resilience, more pressure is generated to open the way for a regime shift (Smith, 2007; Turnheim and Geels, 2013). This highlights the importance of scrutinising regime actors' expectations towards the landscape level for understanding the transition process. Meanwhile, niche actors could leverage narratives of needed change (expectations about future developments of the landscape level) to create cultural legitimacy for niche technologies and ensure they are accepted by the broader public (Geels and Verhees, 2011). When such narratives created by niche actors are being articulated and acknowledged by the regime actors, it could potentially bring niche technologies into regime actors' searching sphere (Turnheim and Geels, 2013, 2019). For example, renewable energy could be labelled as a promising solution to social or environmental issues (e.g. climate change or air pollution). This may create cultural and political legitimacy for the sector. When this happens regime actors may consider investing seriously in renewable energy as a necessary step for a future clean, low-carbon power supply. They feel under pressure to respond to what they now perceive as a serious threat to their business created by climate change at the landscape level. However, they will not invest in regime change if they still believe in the resilience of their seasoned strategies to respond to future threats and opportunities.

*2) Breadth of alignment between actors' expectations at regime level*

When there is sparse alignment between niche and regime actors' expectations about future developments at regime level, it refers to a situation in which neither niche nor regime actors question the regime's resilience to respond to internal crises and/or external pressures. In such a case, niche actors may aim for limited niche development because acceleration is not seen as a viable strategy. Niche development is mainly regarded as an add-on to the mainstream markets: a small market niche at best. When the opposite situation begins to emerge and niche and regime actors broadly share expectations that the dominant regime not only at risk but may fall apart because it can no longer respond to future threats and opportunities, it indicates that regime actors have started to question the regime's resilience. This also means that they are searching for alternatives, which could open spaces for niche acceleration. This search process will have to become focused on specific paths of niche acceleration.

*3) Breadth of alignment between actors' expectations at niche level*

The measurement of expectations at niche level plays a crucial role and has been discussed mostly in comparison with the other two levels in transition studies. Only when niche and regime actors share expectations about the viability of specific niche technology will regime actors mobilise resources to support the development of the niche (Geels et al., 2012). SNM studies have identified the robust alignment of expectations as an essential way to enrol other actors for niche acceleration (Geels and Raven, 2006; Schot and Geels, 2008).

### **Step 3. Building alignment patterns**

This third step introduces the systematic combination of steps 1 and 2. Now we have finished the assessment of actors' expectations at three separate levels (step 1) and the assessment of three degrees of breadth at each level (from broad, to selective, to sparse). Theoretically, we are able to distinguish 27 ( $3 \times 3 \times 3$ ) different types of alignment combinations between niche and regime actors' expectations during the transition process. These are presented in Figure 3.2.

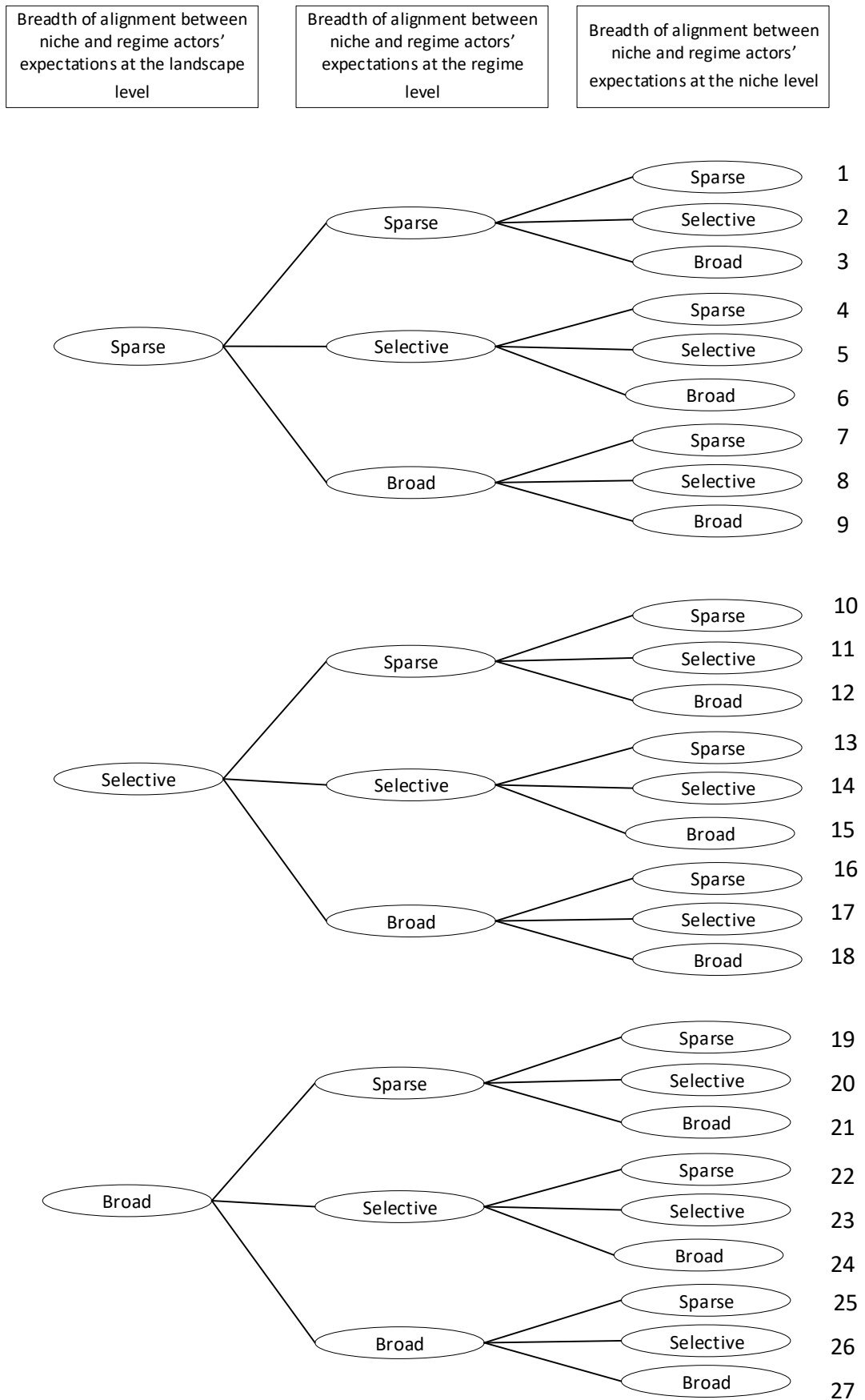


Figure 3.2. Typology of 27 theoretically possible alignment dynamics between niche and regime actors' expectations.

In reality, however, not all of these options will be relevant for our research question that aims to understand the connection of alignment between niche and regime actors to niche acceleration. Drawing on sustainability transitions literature, we can reduce the 27 to 12 possible types by considering the following. First, we can exclude the sparse alignment between niche and regime actors' expectations at all three levels (type 1, in Figure 3.2) as this type does not contribute to niche acceleration. Second, landscape-level expectations are more general than expectations at the other two levels, and therefore actors are more likely to share such general expectations (Konrad, 2006). In other words, we may consider such sharing as a precondition for alignment of expectations at the two other levels. Based on this observation we can exclude alignment patterns for types 2, 3, 4, 5, 6, 7, 8, 9, 16, 17 and 18 where actors share broader alignment at niche and regime level than at landscape level. These are dismissed as unrealistic scenarios. Third, sustainability transition literature indicates that regime actors are generally locked into their existing routines. Regime actors may invest in some niche development, for window dressing or exploration of future opportunities, but certainly not in niche acceleration. For this to happen, regime actors first have to begin questioning the regime's resilience. Therefore, we exclude the types of alignment 12 and 21, where regime actors agree on the strategic importance of specific niches, not just for the sake of new opportunities, but also as a serious future to invest in, but they do not agree on the ability of the regime to respond to sustainability challenges. They are dismissed as unlikely scenarios. For a similar reason alignment type 15 is excluded: it is unlikely to have broad alignment at niche level (i.e. all niche and regime actors share expectations of niche development) while holding selective alignment at the landscape and regime level.

For the remaining 12 types of alignment (types I–XII in Figure 3.3), based on the proposed two dimensions (breadth and depth of alignment), we can distinguish three different basic alignment patterns:

**Weak alignment** refers to a situation in which niche and regime actors have selective alignment at the landscape level and various alignments but never a broad alignment or a simultaneous selective alignment at the two other levels (types I–III); or a situation when there is broad alignment at the landscape level but this has not resulted (yet) in selective alignment at either regime or niche level (type V). For all these types, niches are invisible or less attractive to regime actors. For the alignment types I and V, niche and regime actors share limited expectations of both niche and regime's development. Regime actors are deeply embedded in their routines and believe optimisation is a viable way to proceed. They generally do not share expectations with niche actors, or they do not recognise niches as a threat to the regime's future. Moreover,



at the early stage of niche development, niche actors may focus on the niche and have no clear visions of how the process of regime destabilisation may happen. Niche actors have limited social networks, which are less stable, and the niche technology improves within a protected space where it is isolated from the dominant selection environment. Niches may expand if there is leeway outside the mainstream market, but growth is limited.

Alignment type II may evolve from a situation in which some regime actors built a network with niche actors; however, they see the niche as a small market instead of a threat to the regime. This pattern leads to very limited niche development, especially when there is insufficient pressure from the landscape level. Alignment type III emerges when regime actors start to question the regime's resilience and expect that it will be unable to adapt to external pressures. However, this expectation does not necessarily lead regime actors to move towards investing in a potential new regime if they are not convinced of the performance of niche technologies or opportunities for niches to expand. In this situation they feel they need to stick to a regime optimisation pathway or shift to other more convincing niches. As we will discuss below, in our case study, when the coal power regime actors faced questions about their capability to fulfil the fast-growing electricity demand, they anticipated that the potential of wind and solar power development was limited compared to competing alternatives such as hydropower and nuclear power. Therefore, the limited alignment of expectations between niche and regime actors at the niche level indicates that their limited resources could not be mobilised towards the expansion of niches, thus hampering niche acceleration.

**Medium-strong alignment** refers to a wide range of situations, including ones where niche and regime actors have selective alignment at all three levels, but not broad alignment (type IV); or broad alignment at landscape level and selective alignment at niche level, but regime actors still maintain the resilience of the dominant regime, resulting in sparse alignment at this level (type VI); or broad alignment of expectations about future developments of the landscape level, which has resulted in selective or even broad alignment about regime incapability but not yet any alignment about specific niche acceleration (types VII, X). In all of these situations there are aligned expectations between niche and regime actors, but it is limited to specific levels or actors. Expectations are not aligned across all three levels.

In alignment types IV and VI, some regime actors begin to express expectations about a bright future for a niche technology. Niche actors also begin to envision the future regime they aim to build, providing an alternative to the dominant socio-technical system. This imagining, for example, the renewable energy (RE) penetration of China's future energy system in our case, could act as a platform for aligning niche and regime actors' expectations at all levels, building

the conditions for niche acceleration. However, limited questioning of the regime's resilience and the consequences of landscape pressures may restrict large-scale investment in niche development (Schot and Geels, 2007; Turnheim and Geels, 2012, 2013). But even when regime actors begin to question regime resilience and are starting a "more distant search and exploration of technical alternatives" (Turnheim and Geels, 2013, p. 1754), they may invest in multiple niches leaving limited resources for specific ones (as for alignment types VII and X).

**Strong alignment** refers to alignment types VIII, IX, XI and XII, which have broad alignment at landscape level and at least selective alignment of expectations at both niche and regime level. In this situation niche acceleration is highly probable. As argued by Smith (2007), an "influential niche enlists a broad network of actors in support of its socio-technical practice and the future regime it prefigures. Supportive actors must include producers, users, third parties (e.g. regulators, standards institutes, investors) and policy-makers" (p.430). When regime and niche actors align their understandings of landscape developments, it provides an opportunity for niche actors to mobilise landscape pressure as a resource for articulating concrete regime pressures (for example, the perception of climate change exerts strong pressure on the fossil-fuel-dominant regime towards RE). Moreover, strong alignment between niche and regime actors' expectations at regime level indicates regime destabilisation, which contributes to the further breakthrough of niches (a hypothesis developed by Schot and Geels (2007) and supported by Kanger and Schot (2016)).

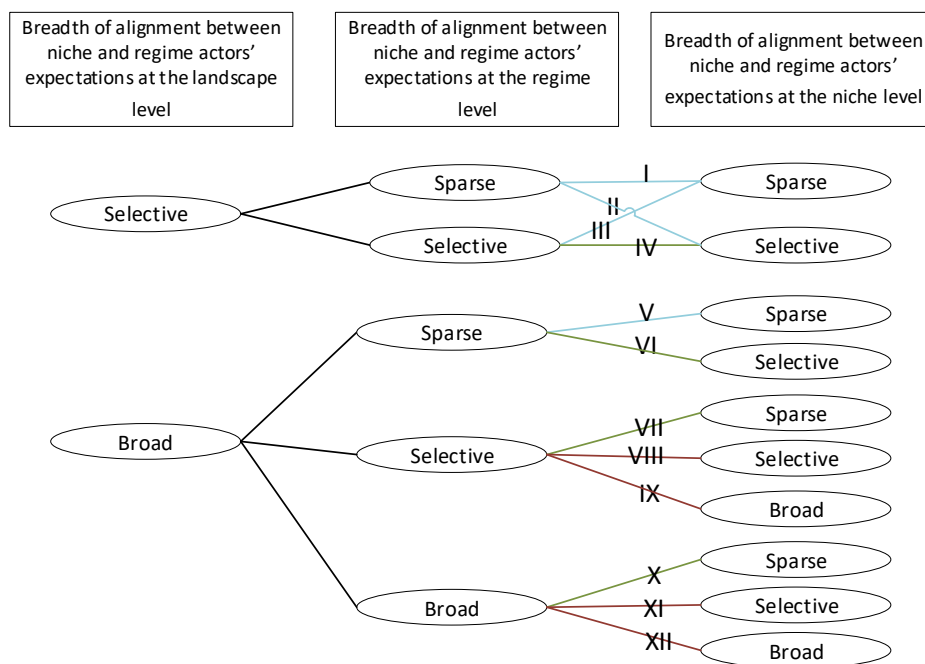


Figure 3.3. Different alignment patterns between niche and regime actors' expectations.

### 3. 2. 3 Relating alignment patterns to niche acceleration

Our theoretical framework aims to connect alignment patterns to niche acceleration in the following way: we would expect niche acceleration to happen following strong alignment, but this process may gain some momentum during the medium-strong alignment phase. This still raises the question of how we establish whether niche acceleration has happened. Niche acceleration is not just about adopting new products. They are part of a transition process that leads to the emergence of a new socio-technical system. A core aspect of such a new system is the development of new rules; in other words, it is a regime formation or institutionalisation process (Fünfschilling and Truffer, 2014). Such a process implies that a new system gains momentum or moves from a situation of fluidity to a more stable one. Schot and Geels (2007) have argued that such a stabilisation of rules is a necessary precondition for niche acceleration, and this hypothesis has been confirmed in historical analysis of the development of the automobile regime (Kanger and Schot, 2016).

But how do we know whether institutionalisation is happening? Measuring this can be complex (see discussion of different stages of institutionalisation by Tolbert and Zucker (1999) and Fünfschilling and Truffer (2014)). For our case study, we use a simpler measurement building on innovation diffusion studies, in particular the work of Rogers (2010). These studies are focused on diffusion of products, which is different from system diffusion (Rotmans et al., 2001). Yet by focusing on the diffusion of a focal technology of a new system, innovation diffusion studies may still contain relevant insights (Geels and Johnson, 2018; Van der Kam et al., 2018) and diffusion curves are often used in sustainability transition studies (Rotmans et al., 2001; Elzen et al., 2012a; De Haan et al., 2016; Kanger and Schot, 2016).

Rogers (2010) distinguished five groups of buyers with different personal profiles adopting new technology at different sequences of time. Moore (1991) argued that there is a chasm in the diffusion process around a 16% threshold, since it is very difficult to move from the early adopters into the early majority group (see Figure 3.4). Early adopters are visionaries; they want what others do not have and are happy to promote a discontinuity between old and new ways and are prepared to champion these against entrenched resistance. People and organisations in the early majority group want to rely on a well-established reference and support infrastructure and follow a social norm. When the early majority start to adopt a new product, it indicates this new product or technology is becoming part of the mainstream. This is a very good description of what happens in a niche, and in the process of moving from a niche to a regime (Schot and Geels, 2008). We argue that the 16% threshold is based on the idea that adopters at that point move from being driven by specific conditions (as in a niche) to accepting

the use of technologies as a consequence of a new social norm and a system being put in place to support this norm. So, adopters become more rule-driven because the niche innovation begins to stabilise.

Based on the above considerations we are able to specify the notion of niche development. When the market share of wind or solar energy is below 2.5% (group of innovators) we assume a slow niche development. When the market share is between 2.5% and 16%, we assume a moderate niche development (group of early adopters), and when the market share is above 16%, we assume a substantial niche acceleration (moving into the group of early majority).

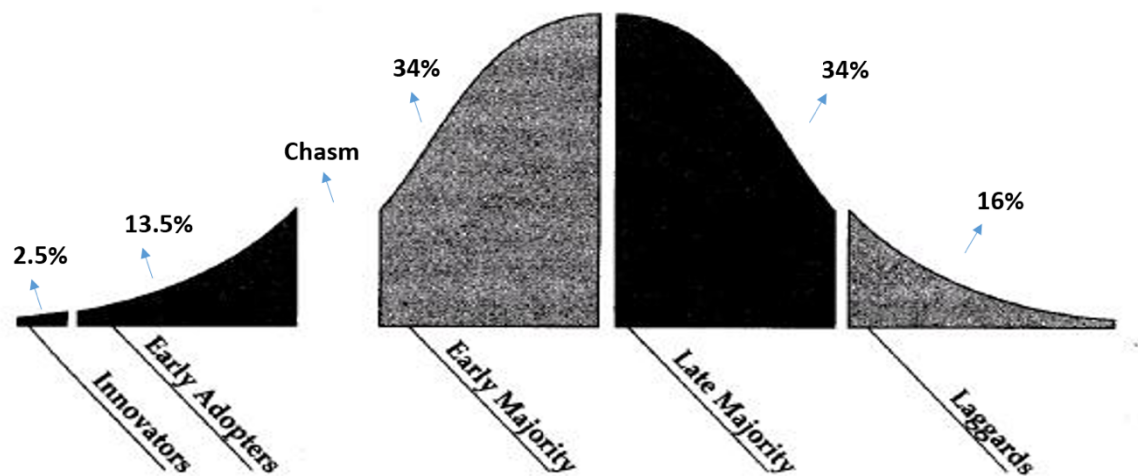


Figure 3.4. Revised technology adoption lifecycle.  
Source: Adapted from Moore (1991) and Rogers (2010)

### 3. 3 Methodology

#### 3. 3. 1 Specifying the framework for our case studies: niche acceleration

Diffusion studies express the market share of new technologies in terms of number of adopters; however, we think relative market share is a better indicator because it automatically takes into account market shares of competitors (other niches) and the decline of the dominant regime. We have used the market share of annual newly installed capacity for wind and solar and included the figures of other niches and installed capacity of coal power plants (see Figure 3.5). We could have also taken the increasing rate of electricity generation or cumulative installed capacity, but data are lacking.

When we apply these thresholds to our two cases, the following picture emerges. For the wind power case we can distinguish three stages of niche acceleration: Stage 1: 2000–2007, slow niche development; Stage 2: 2008–2010, moderate niche development; and Stage 3: 2011–2017, substantial niche acceleration. During this last phase, wind power oscillates between moderate

and substantial niche development but on average is still above the 16% threshold (average = 16.42%). Solar power development can be divided into three similar stages: Stage 1: 2000–2012, slow niche development; Stage 2: 2013–2015, moderate niche development; and Stage 3: 2016–2017 substantial niche acceleration.

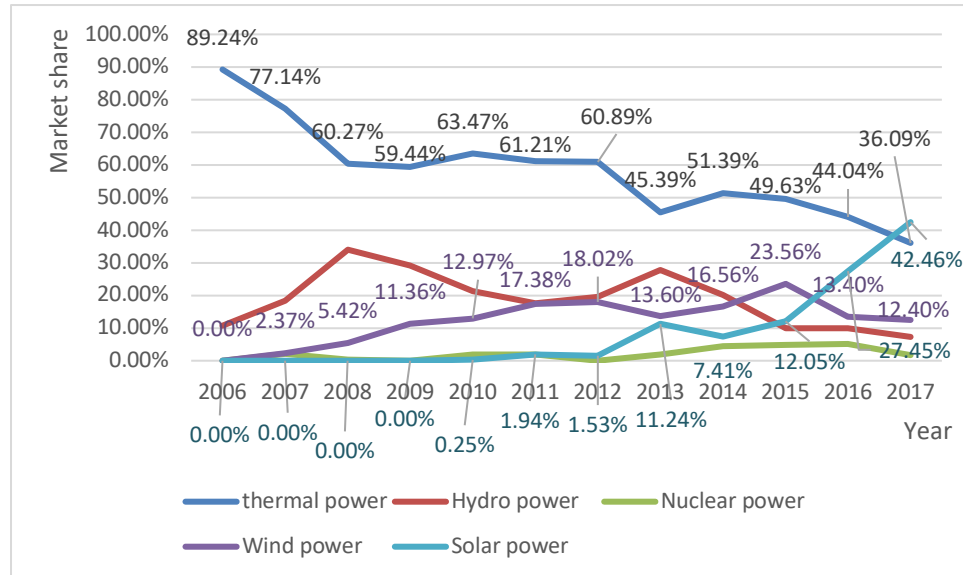


Figure 3.5. Market share of newly installed capacity per year: 2006–2017

Source: from China Electricity Council, calculated by the authors.

### 3. 3. 2 Specifying niche and regime actors

Our framework focuses on alignment between a heterogeneous set of niche and regime actors in a socio-technical system but does not specify how many actors need to be aligned. This needs to be done for each case study separately. Therefore, we first have to identify the main stakeholders for each case by looking at the entire value chain, including generation, transmission, distribution and retail (Stenzel and Frenzel, 2008). For our case studies, we have identified the actors after the reform of China's electricity sector in 2002. In this reform, China's planning-based, centralised electricity sector was transformed into a substantially more market-based system with more diversified actors (Ma and He, 2008; Williams and Kahrl, 2008). The State Power Corporation, which was in charge of generation, transmission and distribution, was split into 11 new corporations: two grid operators (State Grid Corporation of China and China Southern Power Grid) in charge of transmission and distribution across China (apart from the western part of Inner Mongolia); 'Big Five' power generators; and four other auxiliary corporations (Ma and He, 2008). China's current electricity sector still has the same structure (Zhao et al., 2016).

The key stakeholders in our two cases include: central government; research institutes; manufacturers; the grid company; thermal power companies; the financing agency; wind and

solar power generators; industry associations; users; NGOs and green organisations (Zhao et al., 2016; Mori, 2018). We acknowledge that the key actors may change over time along with the development of wind and solar power. For example, the wind and solar power industry association and large industrial users started to play a role at a later stage of development.

To define the medium-strong alignment pattern, the threshold that we used in our two cases largely depends on the shifting of key actors' expectations. In our cases, the key regime actors are the central government, coal power generators and the grid company; the key niche actors are wind and solar power generators and the manufacturing industry (as depicted in Figure 3.6). For example, when any two of the three key regime actors share expectations with the niche actors, we categorise this as selective alignment at the niche level. Sparse alignment at the niche level refers to fewer than two of the key regime actors aligning with the key niche actors. Selective alignment at regime level refers to one of the two key niche actors sharing expectations with regime actors. Sparse alignment at the regime level refers to none of the key niche actors sharing expectations with regime actors. Broad alignment at niche/regime level refers to all of the key regime actors aligning with the key niche actors' expectations.

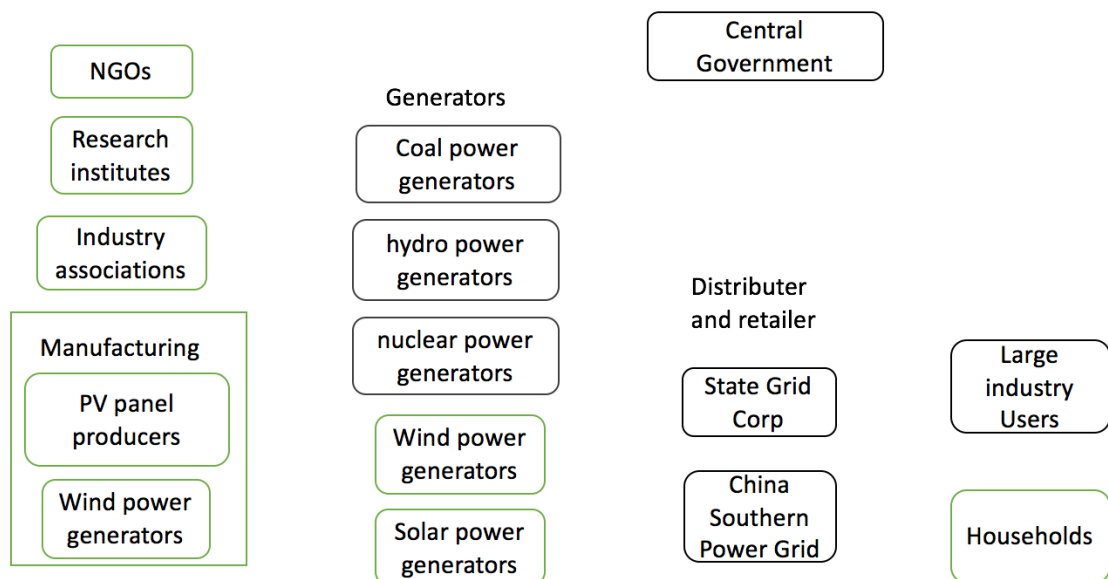


Figure 3.6. Key stakeholders in China's electricity sector.

Legend: Rectangles with black lines depict regime actors; Rectangles with green lines depict niche actors.

### 3. 3. 3 Data collection and analysis

Data collection included: (i) 31 semi-structured and 6 informal interviews with relevant actors; (ii) a workshop<sup>9</sup> with 22 participants, both niche and regime actors; and (iii) desk-based research, in particular retrieval of news from relevant websites, professional journals and organisation reports.

The interviews were conducted by the first author between October 2017 and March 2018. Using interviews to collect data on actors' expectations has several challenges. First, the interviewees may have implicit expectations that they do not easily express. Second, they may hold retrospective bias when asked about their perceptions of historical events.

To overcome these challenges, multiple experts from similar groups were interviewed to reveal expectations and limit individual bias (Eisenhardt and Graebner, 2007). For example, the study included four interviewees from central government so they could validate each other (see Appendix Table A.1). Moreover, the interviews were designed to include cross-checking questions. For example, wind and solar power investors were asked about the grid company's expectations of wind and solar power at certain development stages, and vice versa. This cross-checking was also important to identify alignment patterns among actors. If actors expressed different expectations or expectation alignment was unclear, additional data was sought through archival data sources.

To develop the interview questions, we used the items presented in Table 3.1. We asked interviewees questions related not just to their own expectations, but also to expectations of other actors for triangulation purposes. In order to allow the interviewees to speak relatively openly, they were guaranteed confidentiality. All of the semi-structured interviews were audiotaped, and each interview lasted around one hour. Most interviews were conducted in Mandarin, then transcribed and translated from Mandarin to English. The six informal interviews were conducted at a later stage of the fieldwork (January–February 2018). They were conducted in an unstructured way and used to discuss sensitive issues, such as expectations from coal and grid companies, and to query inconsistencies. These were not recorded.

The workshop took place in March 2018 with all authors present. The aim was to discuss the historical development (through selected key events) of wind and solar power development between 2000 and 2017 and agree on niche development phases and the relationship between main actors during the development process, in a setting designed to build consensus. The first

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<sup>9</sup> This workshop was a Transformative Innovation Policy Consortium pilot with a specific objective of constructing a timeline of the transformative innovation learning history and the specific role of main stakeholders during wind and solar power development in China (2000–2017).

author presented reports on the wind and solar case studies. During the workshop, we collected data through presentations, plenary discussions and facilitated group discussions. Specifically, we conducted two focus group discussions on wind and solar power.

The archival data included: articles from China's largest professional electric power news website,<sup>10</sup> BJX: <http://www.bjx.com.cn/>; institutional reports, such as the annual report of China's electric power development produced by the China Electricity Council from 2001 to 2017, and reports produced by the State Grid from 2015 to 2017; professional journal articles, including China's professional journals on RE, <Solar Energy>, <Wind Power>, <State Grid>; and key government policy documents, such as the <Renewable Energy Development Five-Year Plan>, <Energy Development Five-Year Plan>, <Energy Production and Consumption Revolution Strategy>.

Our data analysis aimed to produce an assessment of alignment patterns between niche and regime actors' expectations at different niche development stages. Alignment patterns had to be identified at three different levels (niche, regime and landscape). For the niche and regime levels we looked at five dimensions: Science and Technology (S&T), Political, Industry, Market and Culture. Our analysis started with coding using keywords from Table 3.1. These keywords cover the five dimensions for both niche and regime levels based on a selective literature review, which includes (Konrad, 2006; Truffer et al., 2008; Turnheim and Geels, 2013; Kriechbaum et al., 2018; Budde and Konrad, 2019).

Table 3.1. Content of expectations at the landscape, regime and niche level in five dimensions of the socio-technical system

Socio-technical system dimensions	Landscape level	Regime level	Niche level
S&T	Future political, economic, environmental and societal development	Future innovation capability of regime technology in adapting to external pressure	Specific project/product/organisational future performance; future technological performance (technology advance rate; stability; perceived uncertainty (Meijer et al., 2007); competition between other technologies)
Political		Policy and government support; laws; regulations; guidelines; standards	Stable long-term regulations, laws, supporting policies, political commitments, political legitimacies

<sup>10</sup> All news titles from 2000 to 2007 were downloaded to identify the key relevant information. From 2008 the search used keywords "solar power (太阳能)", "wind power (风能)", "thermal power/coal power (火电/ 煤电)", "electricity (电力)", "renewable energy (可再生能源/ 新能源)" because the annually increasing amount of news makes it almost impossible to read all the titles after 2007. These keywords were also applied to identify relevant journal articles.



Industry		Industry capability, organisational capability, complementary assets (e.g. infrastructures); financial capability	Manufacturing capability; price and supply of materials and other resources; accessibility of complementary assets, e.g. infrastructure and other resources (material, human and financial resources availability)
Market		Market supply; market structures; users' preferences; market rules	Expectation of future market/profitability, e.g. Does renewable energy have a future in the energy mix? How large will that be? How fast will it increase?
Culture		Social acceptance of regime technology; changing value priorities (economic efficiency, environmentally friendly, safety priority, low carbon preference etc.)	Social meanings and functions of the niche technology, e.g. the role of renewable energy in dealing with energy security, environmental issues or climate change

Coding led to two sets of results: self-evaluated results and other stakeholders' evaluated results. This made it possible to cross-check these two sets of results and see whether they were aligned. If they aligned with each other we put the results (positive/negative/null) into the data result table (see Tables 3.2 and 3.3). If they diverged, we looked at secondary data to reach a conclusion. When the end-result was not consistent we concluded that no alignment had taken place.

Secondary data were also used to fill in the gaps. For example, during the interviews and the workshop, the thermal power companies did not specify their expectations of the landscape before 2006, and secondary data was used to trace their views. For secondary data we constructed a database of relevant articles, which we then coded.

The results are the outcome of a disciplined coding process coupled with triangulation of various sources and interpretation. An important interpretation problem arose because we looked at expectation dynamics across different dimensions of the energy system, from future S&T development to political developments and so on (see Table 3.1). This meant that a range of actors had to agree on expectations concerning each specific dimension. In cases of difference we gave more weight to actors who were evaluating expectations in their own area of work.

The results are presented in the next section, with a table each for wind and solar (Tables 3.2 and 3.3) and a narrative. In the tables we present three types of results for the nature of expectations of each niche and regime actor: "✓" as "positive"; "✗" as "negative"; "–" as "no

information”; we also show how actors’ expectation dynamics at three levels match the niche acceleration stages we identified beforehand and converge with a specific alignment pattern.

### 3. 4 China’s wind and solar power development

#### 3. 4. 1 Alignment dynamics between niche and regime actors’ expectations of wind power

As indicated in Table 3.2, the alignment patterns between niche and regime actors’ expectations of wind power have not been static between 2000 and 2017. Both the content and nature of actors’ expectations of the three different levels are changing over time. There are several actors for whom there is insufficient information on their expectations. However, they do not influence the threshold of alignment patterns between niche and regime actors’ expectations, as their expectations will not strongly influence other actors’ expectations, or they did not explicitly concern themselves with the future of that dimension of the socio-technical system. For example, wind turbine component suppliers are generally less concerned about the future of the coal regime; instead their expectations are more closely connected to the potential future of the market of niche development.

Table 3.2. Niche and regime actors’ alignment of expectations of wind power niche development (2000–2017).

Categories of actors		Stage 1: 2000–2007			Stage 2: 2008–2010			Stage 3: 2011–2017		
		Landscape	Regime	Niche	Landscape	Regime	Niche	Landscape	Regime	Niche
Regime actors	Coal power companies <sup>11</sup>	✓	×	×	✓	×	×→✓	✓	×→✓	✓
	Grid companies	–	×	×	✓	×	×	✓	×→✓	×→✓
	S&T research institutes	–	×	×	–	×	–	✓	–	–
	Electric power association	✓	✓	→✓	✓	✓	✓	✓	✓	✓
	Central government	✓	✓	→✓	✓	✓	✓	✓	✓	✓
	Large industrial users							✓	✓	×→✓

<sup>11</sup> As an example, a positive checkmark for coal power companies’ expectations at the landscape level indicates that they perceive pressure from future development at landscape level which may undermine regime stabilisation.

	Financing agency	–	x	x	–	x	x	–	x→√	√
Niche actors	Wind turbine suppliers	–	–	√	√	x	√	√	√	√
	Wind power generators	–	–	–	√	–	–	√	√	√
	Component suppliers	–	–	√	–	–	√	√	√	√
	S&T research institutes	–	x	√	–	–	√	√	→√	√
	Wind power association				√	√	√	√	√	√
	NGOs	√	√	√	√	√	√	√	√	√
Alignment patterns between niche and regime actors' expectations		Selective	Sparse	Sparse	Broad	Sparse	Selective	Broad	Selective→Broad	Broad
		<b>Alignment pattern 'I'; Weak alignment</b>			<b>Alignment pattern 'VI'; Medium-strong alignment</b>			<b>Alignment pattern 'XII'; Strong-alignment</b>		

Legend: “√” as “positive” expectation; “x” as “negative” expectation; “–” as “no information”; “→” indicates changes occur.

Shadowed areas depict actors who have not played a significant role at that specific stage.

### Stage 1: 2000–2007 Weak alignment

Between 2000 and 2007, there was weak alignment between niche and regime actors' expectations (pattern I in Figure 3.3 with selective alignment at the landscape level and sparse alignment at regime and niche levels). Although at this stage several incumbent actors, such as the central government and the electric power association, started to realise the unsustainability of coal power and energy security issues, there was limited articulation of the landscape pressures by niche actors.

Generally, at this stage, renewable energy took place in the niche market, rural areas with less access to electricity or remote areas with weak grid infrastructure. Niche technology experts articulated the market potential of wind power technology, which could be domestically commercialised and industrialised with the government's policy support (Shi, 2001). However, even the central government and the electric power associations started to pay attention to wind power development, although less priority was given compared to hydropower and nuclear power. Wind power did not attract significant attention from other industry regime actors, in particular from power generators and the grid company.

There was widespread sharing of expectations among different actors of the short-supply issues of China's electricity system, which would be accelerated by rapidly increasing electricity demand to fuel economic growth. Pessimistic views about the levels of domestic coal reserves in China, which could fulfil demand for 20 years at most, were widespread in the public news (BJXnews, 2005). This led to large investment in hydropower construction rather than wind power (BloombergNEF, 2018). Narratives criticising the unsustainability and environmental impact of coal power emerged (China Electricity Council, 2002). However, values around environmental protection and sustainability were not explicitly or strategically shared among niche and regime actors (Urban et al., 2012).

### **Stage 2: 2008–2010 Medium-strong alignment**

There is medium-strong alignment between niche and regime actors' expectations at this stage (pattern VI in Figure 3.3, with broad alignment at the landscape level, sparse alignment at regime level, and selective alignment at niche level). Alignment at the niche level was broader than during the former stage.

This stage witnessed the nascent shift of China to low carbon development. Green and low carbon emerged as values for economic growth. There was an increasingly high expectation of renewable energy's bright future among different actors in China after the Renewable Energy Law was introduced in 2005. The central government showed increased enthusiasm and commitment to wind power, which was endorsed as the most advantageous renewable energy (Li et al., 2008; Han et al., 2009). In 2009, the central government positioned the renewable energy industry as the strategic emerging industry, one of the engines for China's future green economy growth. It soon became a 'hot spot' for social investment, with a rapidly growing number of wind power manufacturers. The central government introduced a renewable energy mandatory policy in 2007 and large power generators started to invest in wind farms as a long-term development strategy (Wang, 2010). Power generators' commitment to wind power deepened at a later stage following long-term tensions in the coal industry about high coal prices (Wang, 2007; Liu, 2013). This tension weakened their faith in the competitive advantages of the coal power regime. Furthermore, from 2008 onwards, with decreasing wind power plant costs and a belief in long-term positive government support for wind power, power generators started strategically setting up subsidiaries for wind power businesses (Chen, 2012). However, wind power was treated as an add-on to the market with both niche and regime actors less explicitly showing belief that thermal power would be substituted by RE (Iizuka, 2015). Moreover, wind power was regarded as "rubbish electricity" by the grid company, which stated that because of the intermittency of wind power, its large-scale integration in the grid would undermine the

safety of the electricity system (Yuan et al., 2012). This lack of support from the grid company led to China's wind power suffering from high curtailment rates at a later stage (Zhao et al., 2012a).

### **Stage 3: 2011–2017 Strong alignment**

At this stage there was broader alignment between niche and regime actors' expectations at three levels (pattern XII in Figure 3.3). Actors' perceptions of pressure from the landscape level became clearer than previously. Expectations were that the future of the energy system should be "clean, low carbon, safe and efficient" (NDRC and NEA, 2016a). There was a deep congruent understanding of the urgency to restructure and transform China's current coal-dominated energy supply system to mitigate climate change and domestic air pollution issues (NDRC and NEA, 2016b). This policy document sets 15% and 20% as minimum targets for non-fossil fuel in the energy mix by 2020 and 2030 (see Appendix Table C.1). Increasing the proportion of renewable energy in the energy mix was reframed as necessary to achieve the central government's carbon emissions reduction targets. Wind power technology was regarded as one of the main technologies that could help China achieve a low carbon strategy (Shi, 2014).

Government and industry actors regarded the wind power industry as mature enough for the technology to be scaled up and put into commercial application across China without subsidies by 2020 (He, 2016; NDRC, 2016). The big coal power companies started to invest strategically in renewable energy, especially wind power. Since 2016, there has been a fast shift of regime actors' expectations about the coal power regime's resilience to external pressures: "the more foresighted companies... such as SDIC Power (the State Development and Investment Corporation), are already disposing of coal-fired power assets. China's five major power companies are much less inclined to invest in new capacity and are speeding up divestment from some old or poor quality assets" (Zhang, 2017). Furthermore, with the large increase in installed wind capacity, the grid company improved its infrastructure capabilities and dispatch practices to integrate more renewable energy. The State Grid Corporation started issuing a white paper <Promote the Renewable Energy Development> every year since 2015. Clean and low carbon became core values of its business strategies.

#### **3.4.2 Alignment dynamics between niche and regime actors' expectations of solar power**

The alignment between niche and regime actors' expectations of solar power at the three levels has been changing between 2000 and 2017 (see Table 3.3). The strong alignment between niche and regime actors' expectations about future developments of the niche level formalised almost

at the same time at the regime level, distinguishing it from wind power. For the latter, the build-up of broad alignment at the niche level took place before it achieved the same breadth of alignment at regime level. We present the storyline of actors' expectations for solar power development, drawing attention mostly to the evolution of expectations at the niche level as the regime actors' expectations about the other two levels (regime and landscape) have been largely presented in the wind power case. However, we will present how the niche actors perceive the future of landscape-level and regime-level development.

Table 3.3. Niche and regime actors' alignment of expectations of solar power niche development (2000–2017).

Categories of actors		Stage 1: 2000–2012			Stage 2: 2013–2015			Stage 3: 2016–2017		
		Landscape	Regime	Niche	Landscape	Regime	Niche	Landscape	Regime	Niche
Regime actors	Coal power companies	√	×	×	√	×→√	×	√	√	×→√
	Grid companies	→√	×	×	√	×	×	√	×→√	×→√
	S&T research institutes	–	×	–	√	–	–	√	–	–
	Electric power association	√	√	×	√	√	√	√	√	√
	Central government	√	√	×→√	√	√	√	√	√	√
	Financing agency	–	×	×	–	×	×→√	–	√	√
Niche actors	Solar panel suppliers	–	–	√	√	–	√	√	√	√
	Solar power generators	–	×	–	√	–	√	√	√	√
	S&T research institutes	√	–	√	√	–	√	√	√	√
	Solar power association	√	√	√	√	√	√	√	√	√
	Households/ large industrial users	–	–	–	–	–	–	√	√	√
	NGOs	√	√	√	√	√	√	√	√	√
Alignment patterns between niche and		Selective	Sparse	Sparse	Broad	Selective	Sparse	Broad	Broad	Broad

regime actors' expectations	<b>Alignment pattern 'I'; Weak alignment;</b>	<b>Alignment pattern 'VII'; Medium-Strong alignment</b>	<b>Alignment pattern 'XII'; Strong alignment</b>
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Legend: “√” as “positive” expectation; “x” as “negative” expectation; “–” as “no information”; “→” indicates changes occur.

### **Stage 1: 2000–2012 Weak alignment**

There was a weak alignment between niche and regime actors' expectations of solar PV (pattern I in Figure 3.3), with selective alignment at the landscape level, sparse alignment at the regime level and niche level.

In the early 2000s, private entrepreneurs (such as the CEO of Trina Solar) articulated that renewable energy would be a potential substitute for fossil fuel in the long term (Huang et al., 2016). However, there were relatively low expectations of the market potentials of solar PV, as it was widely regarded as too expensive to be deployed in the country at scale and not competitive in the market compared with conventional power in the short term. “When the founder of Suntech told us that he would like to build up 10MW solar PV production line in 2001, we feel like it is impossible, there won't have market for that massive production” (former national policymaker, Beijing, 12 Dec. 2017). The domestic deployment of solar PV was predominantly targeted at remote areas without electricity access, for example, in western China. As a stand-alone energy system, solar PV was believed by the central government to be suitable for areas with limited access to electricity and weak grid infrastructure capability (NDRC, 2007), but too expensive to be widely used in the Chinese electricity market. Meanwhile, solar power was believed to be less competitive than other clean technologies such as hydropower, nuclear power, wind and biomass (Li et al., 2007b). According to the <Medium-long term development plan for the RE (2007)>, the total capacity of solar power (PV and thermal together) was set at 300MW by 2010, reaching 1800MW by 2020, while the targets set for wind power were 5,000MW and 30,000MW respectively. There was less explicit articulation of the strategic role that solar PV could play in China achieving a low carbon future.

With the fast take-up of China's solar power industry because of the global market, especially the expanding European market (Marigo et al., 2008), industry actors started to believe that the potential domestic market would increase in the near future with the continuous reduction of solar panel costs. Especially after the then biggest manufacturing company, Suntech Power Holdings, went public on the New York Stock Exchange in 2005, showing that solar PV could bring great wealth, the private enterprises started to flood into the solar PV manufacturing industry because of its bright future. This high expectation further burgeoned when it was

labelled as a strategic emerging industry by the central government in 2009. However, these expectations did not translate into domestic deployment (Fischer, 2012).

### **Stage 2: 2013–2015 Medium-strong alignment**

The alignment between niche and regime actors' expectations at the three levels was medium-strong (see Figure 3.3, pattern VII), with broad alignment at landscape level, selective alignment at regime level and sparse alignment at niche level. With increasing concern about climate change and domestic air pollution, the thermal power regime started to be questioned by both niche and regime actors. However, collective expectations between niche and regime actors were less strong compared to the later stage.

As solar panel costs fell, solar PV was perceived as a potential option for future clean energy in China. Especially after the Fukushima nuclear accident in 2011, solar PV was seen as a safer alternative. Moreover, it was perceived that there would be limited potential to increase the market for hydropower in China. Industry actors believed that solar PV was a sunrise industry with great potential to fuel the future green economy. This expectation was mobilised to lobby the central government to support the domestic market (Huang et al., 2016). Furthermore, solar PV was perceived to have a potential large market with diversified applications, not just for centralised power plants but also for distributed solar PV panels. The flexibility of solar PV systems and the multiple emerging business models further reinforced expectations for fast increasing domestic market.

### **Stage 3: 2016–2017 Strong alignment**

The alignment between niche and regime actors' expectations at the three levels was strong (see Figure 3.3, pattern XII), with broad alignment at all three levels.

From 2016, the coal power regime began to destabilise. Coal power was criticised as unsustainable, with negative impact on air quality and water consumption (Greenpeace, 2017). Along with emerging oversupply issues in the electricity market, there were increasingly high expectations that coal power in China would peak in 2020 (Zhang, 2016c). The central government showed determination to cap coal power plants. During a roundtable discussion of the transition of China's electricity system for the 13<sup>th</sup> Five-year Plan in January 2016, the experts agreed that the golden age of coal power had passed (NRDC, 2017). The successful decoupling of China's economic growth from coal power was considered to have ushered the country into a post-coal era (Duan, 2016; Qi et al., 2016). In December 2017, NEA convened the 2018 national energy conference, during which, for the first time, it officially declared the overcapacity problems of coal power plants in China and that the development of thermal power was



entering a “defusing the risk of overcapacity” stage (Cableac.com, 2018). NEA made a clear statement that with the transformation of the energy system, the future for coal power was to provide a dispatch auxiliary service for renewable energy and to make space for renewable energy generation. Previously, the function of thermal power was believed to be the dominant power “to guarantee the supply of electricity”.

Solar PV has been regarded as an important strategy for big utilities and conventional coal power investors to transform their business towards a clean and low carbon future. With the further decrease of solar panel costs, it has been perceived that by 2020 solar PV panels will be competitive in the conventional power market. The Solar PV Manufacturing Industry Association argued that with the achieving of grid parity, solar PV would become the dominant RE power in China’s energy market. Solar power has a low requirement for physical infrastructure and can be built as a stand-alone energy system, which does not need a large piece of land. It can fit onto the rooftops of existing buildings, a huge advantage over traditional large-scale power plants. These characteristics make it suitable for relieving the energy supply pressure in large electricity loading areas, such as in southern China (Senior experts in solar PV industry association, interview, 2017). The development of solar power is believed to aid the development of a low carbon and clean energy system in China. Moreover, the government has mobilised the development of a distributed solar PV energy system as a strategy to alleviate poverty in China with an objective of adding 10GW capacity to benefit households and villages across the country by 2020 (Geall and Shen, 2018). With the emerging of new business models, financing mechanisms, and further ICT and energy storage technology development, industry actors believe that solar PV will become the dominant new electric technology in China.

### 3. 5 Discussion

Our two cases have demonstrated that expectations play a crucial role in coordinating the alignment process between niche and regime actors. Oriented by their shared expectations, they work collectively to shape the prospective socio-technical structures. Different alignment patterns shape different phases of niche development.

#### 3. 5. 1 Weak alignment and slow niche development

The two cases have illustrated that weak alignment between niche and regime actors’ expectations matches low speed and scale of niche development. Before 2007, when there was weak alignment between niche and regime actors, there was relatively low take-up of wind and solar power (see Figure 3.5). The narrowly shared expectations about niche development could

also explain why at this stage, the policy goals set up by the central government for the wind power could not be achieved.

The correspondence of weak alignment to slow niche development is also validated by the comparative insights drawn across two cases. We see there was comparatively weak alignment between niche and regime actors' expectations towards solar power compared with wind power between 2007 and 2012, resulting in limited take-up of solar power compared with wind power. With higher expectations of wind power, regime actors such as the big utility giants showed more interest in investing in wind power plants when they were confronted with expectations of further stringent policy regulations requiring a shift towards clean and low carbon energy.

### 3. 5. 2 Medium-strong alignment and moderate niche development

The two cases evidenced that medium-strong alignment contributes to moderate niche development. However, niche and regime actors held different types of alignment in the two cases. In the wind power case, there was broader alignment between niche and regime actors at the niche level compared with the regime level, while in the solar power case the two sets of actors had similar breadth of alignment at both levels. Between 2008 and 2010 the development of wind power could be seen as an add-on to the market. Because of the narrower alignment at the regime level, wind power experienced high levels of curtailment. However, as we see in the later stage, when the vision of "clean and low carbon" was widely shared, wind power was further legitimised in the electricity system, and niche actors mobilised this legitimacy to argue for more institutional support to guarantee its generation. In the case of solar PV, the build-up of shared expectations at the niche level encountered a different process. Along with weakened expectations of competing technologies, such as hydropower and nuclear power, rapidly decreasing solar panel costs escalated the expectations of the competitive advantages of solar PV in the market.

### 3. 5. 3 Strong alignment and substantial niche acceleration

As demonstrated in the two cases, when there is strong alignment between niche and regime actors' expectations, their expectations could be translated into concrete goals and requirements of other actors. For example, in 2011, the Energy Research Institute under NDRC issued the <Roadmap to 2050 for China's wind power development>, establishing long-term development targets for installed capacity of wind power to achieve 400GW by 2030 and 1000GW by 2050. Moreover, we see explicit articulations of connecting wind and solar power development with sustainable and clean development at the landscape level. When the clean and low carbon ethos was widely shared in society, with the prospective visions that China needs

for a low carbon transition, the scenarios with high proportions of wind and solar power in the electricity system were generated to urge further actions from corresponding actors (Energy Research Institute of NDRC, 2015).

Furthermore, when the central government share these expectations, it is more likely to implement supporting institutions for niche development. For example, to further stimulate support from the grid company for wind and solar power, in 2016 the central government set minimum annual generation hours for wind and solar power to encourage the utilisation of RE in the electricity mix. As evidenced in the two cases, when there is strong alignment between niche and regime actors, we see their shared expectations being more stabilised and able to be mobilised for more institutional support for wind and solar power's further development. For example, the central government implemented a stringent policy to cap coal power to create space for RE deployment to meet the targets set for non-fossil fuel in the energy mix in 2020. This institutional change contributed further to the fast wind and solar power deployment and the reduction of thermal power plants.

This strong alignment between niche and regime actors created self-reinforcing mechanisms which further contributed to fast system transformation. We see that when the regime is under pressure niche actors start to argue for the necessity of increasing RE to promote clean and sustainable energy revolution. Furthermore, niche actors specifically attempt to reduce coal power regime since 2016 to further increase space for wind and solar power generation in the country's electricity mix. As we see from Figure 3.5, the percentage of yearly new installed capacity of thermal power has dropped by 11.5% (from 82.4% in 2011 to 70.9% in 2017) in seven years. This rapid decreasing of the market share of coal power further weakened coal power investors' expectations of the strategic role of thermal power in future market. Furthermore, with stringent policy regulation from the central government, the coal power regime actors started to question coal power regime resilience. This provided further opportunities for niche actors to articulate potential solutions through the two RE technologies. This strong alignment explains why China's wind power and solar PV installed capacity surpassed its 2020 goals three years ahead of schedule (Finamore, 2019).

### 3. 6 Conclusion

This paper endeavours to make a first contribution to unpacking the alignment dynamics between niche and regime actors' expectations, and how their alignment dynamics contribute to niche acceleration. Our contribution is fourfold. **First**, we conceptualise three alignment patterns between niche and regime actors' expectations: strong alignment, medium-strong

alignment and weak alignment. **Second**, we define three phases of niche accelerations based on technology adoption lifecycle studies and relate them to the three alignment patterns. **Third**, we operationalise our conceptual framework by specifying different phases of niche accelerations and corresponding niche and regime actors in our cases and set thresholds to define different alignment patterns. Moreover, we offer a quasi-quantitative method to map out the alignment patterns between niche and regime actors. **Fourth**, we illustrate the alignment dynamics between niche and regime actors' expectations in two cases of wind and solar power development in China between 2000 and 2017.

Overall, this paper provides a theoretical framework that clarifies how the expectation alignments between niche and regime actors contribute to niche development, including its acceleration. Based on our results we would even argue that alignment dynamics between niche and regime actors' expectations can be seen as a good proxy for expected niche development. These research findings have significant policy implications. They suggest that to accelerate niche development, policy can play a crucial role in shaping the process of building shared expectations between niche and regime actors.

Moreover, our research results challenge the dominant state-led understanding of China's fast RE development and support recent research that has shown tensions and competitions between actors during China's wind and solar power development (Luo et al., 2012; Dai, 2015; Dent, 2015; Luo et al., 2016; Cai and Aoyama, 2018; Shen and Xie, 2018). For example, although the central government held ambitious goals for wind power, these goals were not achieved before 2007. This can be explained through our framework as a result of relatively weak alignment between niche and regime actors' expectations. Post-2007, alignment between the two increased, leading to surpass the central government's targets. Thus, our research framework can offer useful insights to illustrate the evolving coordination and alignment processes between different stakeholders. Our research findings also suggest this dynamic process is crucial for understanding the niche acceleration process in a country such as China. We argue that the proposed conceptual framework can also be used for other cases outside of China, an area for new research.

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## Chapter 4 Article 2

### **Niche shielding dynamics: patterns of wind power development in two Chinese provinces**

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## Abstract

This paper develops the underdeveloped concept of niche shielding in strategic niche management studies. It adds to the existing literature by contesting niche shielding dynamics from two aspects: (i) how niches shield against selection pressure from multiple dimensions of the socio-technical system (science and technology, industry, market, policy, culture); and (ii) how niche shielding unfolds across multiple scales (provincial and national). This paper examines two longitudinal cases of divergent wind power development in two provinces in China, Inner Mongolia, and Jiangsu, as well as on a national scale. The research findings suggest niche shielding may align in certain dimensions while conflicting in other dimensions across multiple scales. These insights generate crucial implications for unpacking the interaction dynamics between niche and regime actors for niche development.

**Keywords:** Strategic Niche Management; Niche shielding; Multi-dimensions; Multi-scale; China; Wind power

## Highlights

- Develops concept of niche shielding from two aspects;
- Shielding may align in certain dimensions, while conflict in other dimensions across multiple scales;
- Suggests non-linear understanding of how to phase out temporary protective spaces;
- Illustrates niche shielding dynamics of wind power development in China's two provinces as well as national scale.

#### 4. 1 Introduction

The concept of niche has been widely accepted in branches of sustainability transitions studies, such as strategic niche management (SNM) (Schot et al., 1994; Kemp et al., 1998; Weber et al., 1999; Hoogma et al., 2002) and multi-level perspective (MLP) (Geels, 2002, 2004; Geels and Schot, 2007). Niche has been conceptualised as a set of rules, distinguishable from dominant rule sets, which offers a protective space that nurtures radical or path-breaking innovations (Schot and Geels, 2008; Smith and Raven, 2012). Niches could be constructed through passive shielding based on a pre-existing selection environment or market niches (Schot and Geels, 2007; Smith and Raven, 2012). SNM studies argue that actors can proactively construct niches through strategic interventions (Kemp et al., 1998). When radical innovations emerge, they generally cannot compete with mature technologies in the market (Schot et al., 1994). The government could proactively set up regulations, subsidies or taxes (Geels et al., 2017) to generate protective spaces that benefit these radical innovations (Schot and Geels, 2008). The feed-in tariff, for example, has been recognised as one successful policy instrument that has contributed to the global rapid diffusion of renewable energy (Fell, 2009; Sovacool, 2010; Alizamir et al., 2016). As renewable energy technology has matured, the feed-in tariff has been slowly reduced in many countries, finally leading to the great success of renewable energy (RE) diffusion (Alizamir et al., 2016). However, there have been cases where the rapid reduction of tariffs has caused a dramatic drop in the installed capacity of renewable energy or resulted in government expenditure being much higher than budget, as observed in the case of Spain's feed-in tariff in 2006–08 (DB Climate Change Advisors, 2009). It raises the questions: How to proactively construct protective spaces through strategic interventions? and How do actors interact to shape this process?

To address this question, this paper builds on insights from the niche shielding concept in sustainability transitions studies. Niches play a role as protective spaces shield against selection pressure from the dominant market, regulations, social norms and values to create separate rules to nurture the growth of radical innovation (Smith and Raven, 2012). When these rules are stabilised, the strategic interventions which create protective spaces will be phased out. According to Boon et al. (2014), the niche development process goes through the stages of niche creation, maintenance and phasing out. Existing niche-based transition studies such as SNM studies argue that temporary protective spaces need to be phased out step-by-step (Kemp et al., 1998; Schot and Geels, 2008; Nill and Kemp, 2009). However, as argued in this paper, this linear step-by-step process understanding of first creating protective spaces (niches) through strategic interventions and then phase out is misleading. It neglects two crucial aspects of niche



shielding dynamics: (i) for successful niche development, shielding has to hold off selection pressure from multiple dimensions of the socio-technical system; and (ii) the shielding dynamic is shaped by the interactions of shielding across a range of levels and scales (local, provincial, national and global).

These two aspects of niche shielding dynamics generate crucial implications for unpacking the interaction dynamics between niche and regime actors for niche development. This paper will examine these dynamics using the case of wind power development in two Chinese provinces, Inner Mongolia Autonomous Region and Jiangsu province, as well as at the national scale. It investigates the following research question: how do niche shielding dynamics unfold for wind power development in two provinces across multiple dimensions and multiple scales (provincial, national)? And how do actors interact to shape these dynamics? Wind power has been established in China's electricity sector and contributed 5% of the country's electricity mix in 2017 (National Energy Administration, 2017). Inner Mongolia is characterised by a historically entrenched coal power regime which, nonetheless, rose to leadership in wind power deployment. Jiangsu province has relatively modest wind power development but has been rapidly catching up in recent years. Instead of focusing on the national level, which has been the predominant level for analysis in existing renewable energy diffusion studies (Chen and Lees, 2016; Zhao et al., 2016; Shen and Xie, 2018), the paper investigates wind power development at the provincial level. The two provinces offer two contrasting cases with divergent niche shielding dynamics.

The rest of the paper proceeds as follows. Section 2 reviews key literature on shielding dynamics for niche development and then discusses two key aspects: multi-dimensional and multi-scale. Section 3 describes the methodology. Section 4 introduces niche shielding dynamics for wind power development in two provinces and nationally. Section 5 discusses how the considerations of the multi-dimensional and multi-scale aspects of niche shielding dynamics offer rich insights for unpacking the interaction dynamics between niche and regime actors in the process of/during niche development. Section 6 concludes.

#### 4. 2 Shielding dynamics for niche development

An evolutionary perspective regards technological change as generally following a certain trajectory, which has been conceptualised as technological regime (Nelson and Winter, 1982) and technological paradigm (Dosi, 1982). Sociologists expanded the concept as socio-technical regime (Schot, 1998; Geels, 2002; Rip and Schot, 2002). This understanding regards technological designs as strongly shaped by related policy, social cultures, networks and social

norms (Rip and Kemp, 1998). The intertwining of different socio-technical elements cause system lock-in and force socio-technical system follow incremental changes.

How does radical or path-breaking innovation such as renewable energy emerge? Levinthal (1998) argued that radical innovation occurs in pre-existing application domains where specific local conditions result in a preference for a new technology. These specific application domains are conceptualised as market niches, which offer protective spaces for the emerging technologies to grow and compete with established technology. SNM studies argued these niches are not just out there (Schot and Geels, 2007). They need to be proactively created and constructed by actors (Schot and Geels, 2008). For the emergence of radical innovation, it is necessary to generate protective spaces through actors' strategic interventions. This is especially true for environmentally friendly technologies, which have been characterised as holding limited advantages in the market. Without proactive interventions, "the journey would not begin at all since market demand does not pull and firms and other technology actors are not pushing for market introduction" (Schot and Geels, 2008, p. 543). Policies have been recognised as one of the main strategic interventions to create such protective spaces.

However, Hommels et al. (2007) argued that active policy-based protection may lead to picking winners who are vulnerable when they encounter the dominant selection environment. The technology may not survive in the market once the protection is phased out, as it could be overprotected, making the technology vulnerable in a real context (Hommels et al., 2007). From their point of view, there will be more chances of success for radical innovations if they are exposed to the risks and protests from the outset. Moreover, once the protection is put in place, its phasing out becomes politically difficult. Some other risks have also been identified, for example, the danger of creating white elephants (Geels and Schot, 2007), and the political challenge of eliminating support for the niches as business sectors may continuously lobby policy support for many years to safeguard their profits (Kemp et al., 1998; Nill and Kemp, 2009).

The debate raises various questions. What constitutes niche protective space? Who is involved in constructing niche protective spaces? How do actors interact to shape niche development dynamics? Smith and Raven (2012) elaborate three properties of niche development: shielding, nurturing and empowering. Niches play a role as protective spaces to shield against selective pressure from the prevailing socio-technical regime. Two different types of shielding can be categorised: passive shielding (market niches as recognised by Levinthal, 1998) and active shielding (recognised as technological niches by Schot et al. (1994); Raven, 2006; Schot and Geels, 2007). The success of niche development depends not only on the shielding process but also on the nurturing and empowering process (Smith and Raven, 2012). Nurturing refers to the

activities that enable niche technology development. This has been most developed by SNM studies. Empowering refers to the political struggles between niche and regime actors, which have been recognised as an important feature for niches to scale up for the final system transformation (Smith and Raven, 2012). This concept has been recently developed by several scholars (Verhees et al., 2012; Kern et al., 2015; Raven et al., 2016). However, the concept of niche shielding has been underdeveloped. As recognised by Schot and Geels (2008), there is limited understanding of “the nature and source of protection of niches that is conducive to its further development, as well as the management of selective exposure” (p. 550). In the following, I will advance the understanding of niche shielding dynamics from two aspects: how it unfolds across multiple dimensions and across multiple scales.

#### 4. 2. 1 Multi-dimensional niche shielding dynamics

Shielding is defined by Smith and Raven (2012) as “those processes that hold at bay certain selection pressures from mainstream selection environments” (p. 1027). However, the mainstream selection environments are multi-dimensional, which contain different selection environments of the socio-technical change (Smith and Raven, 2012). Geels (2004) distinguished five key dimensions of the socio-technical regime (science, technology, policy, socio-cultural, user and market), each with associated institutions, actors, and resources that explain dynamic stability and unfolding trajectories in socio-technical change. Smith and Raven (2012) added industry structures, thus coming up with six dimensions. They argue that each dimension acts to exert selection pressures on niche innovations.

In this paper, I will combine the two dimensions science, and technology into one dimension as science and technology, since both operate closely together in the process of renewable energy technology diffusion. Therefore, I categorise the regime selection environment under five different dimensions: science and technology (S&T), industry, market, policy, and culture (see Table 4.1 for definitions). Radical innovations thus require shielding from selective pressure from these multiple dimensions. For successful niche development, shielding requires coordination between these multiple dimensions of selection pressures to build socio-technical structures for the potential regime. Recent studies have identified that internal tensions among these multiple dimensions suggest regime destabilisation (Karlton and Sandén, 2012; Turnheim and Geels, 2012, 2013). This may create opportunities for further niche take-up (Schot and Geels, 2007). It thus raises the concern of how niche interacts with regime across these multiple dimensions. This closely shapes niche shielding dynamics.

Innovation studies on shielding have predominantly focused on the S&T dimension. It has been widely argued that government should invest in R&D for green innovations, because they are

public goods which lack market incentives for private investors. This has been the focus in conventional innovation policy studies which aim to address market failures (Weber and Rohracher, 2012; Schot and Steinmueller, 2018). Historical projects such as the Manhattan Project (nuclear weapons) and the Apollo Program (spaceflight) could be regarded as typical cases which have grown in a certain selection environment with the support of R&D investment from the government for specific aims. However, as recognised by Steward (2008), these types of shielded projects narrowly focusing on the S&T dimension contribute only to radical technological innovations and have not transformed the systems of production and consumptions. To achieve sustainable development, a socio-technical system perspective is needed (Geels, 2004; Grin et al., 2010). Transformative change has to target the whole system. Therefore, shielding should go beyond the S&T dimension and ultimately coordinate across the five dimensions identified above.

Recent transition studies have identified government's role within market pull strategies (Mazzucato, 2016; Boon and Edler, 2018). Regulations and policies can play a central role (via taxes, subsidies, regulations and standards) in changing economic conditions to support the emergence and deployment of low-carbon innovations (Geels et al., 2017). Apart from the policy dimension, Seyfang and Smith (2007) argued that the protective space could also be generated by promoting or serving divergent values and culture. The grassroots innovations which are aiming for sustainable development, for example, are driven by social needs or ideological commitment rather than profit seeking. As observed by Lovell (2007), the UK's low-energy housing niches are largely driven by entrepreneurial individuals and organisations with strong green values. Moreover, users may have different preferences based on value diversity which can also generate niche markets (Schot et al., 2016). For example, the green movement generated different values from those of the dominant market. Users prefer "independence" and "green electricity" to cheap electricity (Smith and Raven, 2012). In summary, niche protective spaces can be generated through targeted policy instruments, strategic R&D investment, industry deployment, specialised market, or diversified cultural and social values. These protective spaces can shield against selective pressures from multiple dimensions of the socio-technical system.

Acknowledging the multi-dimensional nature of niche shielding is crucial for successful niche development. It has been recognised that shielding which narrowly focuses on a particular dimension may lead to the failure of niche development (Verbong et al., 2008). The functions of shielding should enable more heterogeneous actors to build broad networks to allow the emergence and stabilising of new rules (Schot and Geels, 2008). Success in niche development,

i.e. reaching a stable point in which the niche replaces or fundamentally alters the prevailing socio-technical regime, largely depends on the process of shifting from active to passive shielding across all dimensions of the socio-technical system (Kemp et al., 1998; Steward, 2012). This raises the question, how can shielding be coordinated across different dimensions? What would occur if the shielding were heavily focused on one dimension, such as S&T? Most transition studies focus only on how the shielding from one specific dimension contributes to niche development, and few studies have systematically examined how shielding unfolds across these different dimensions. The failure to recognise that niche shielding covers multiple dimensions may limit the understanding of how and when to phase out temporary protective spaces for radical innovations.

Recent studies (e.g. Mylan et al. (2019)) have recognised niche–regime interactions may operate differently across four different dimensions: business environment; wider policies and culture; user environment; and policy environment. In some dimensions, niches can operate in a pattern which fits with the selection environment of regime (this indicates passive shielding). In other dimensions, niche can operate in a pattern which transforms the selection environment (this indicates active shielding). In this context, both active and passive shielding perform across these multiple dimensions. It thus challenges the previous assumption that niche development is a linear process shift from active to passive shielding.

Drawing upon the discussion by Smith and Raven (2012) and others, as elaborated in Table 4.1, niche shielding dynamics can be investigated from two axes: (a) the *width* of shielding (the number of ‘dimensions’ across which the shielding wards off the regime selection pressures); and (b) the *nature* of shielding (passive or active). In this study, I will follow the typology of five dimensions recognised above and will trace how the niche shielding dynamics unfold across these dimensions over time (see Table 4.1).

Table 4.1. Five dimensions of niche shielding dynamics

Source: based on Geels (2004) and Smith and Raven (2012)

Five dimensions	Descriptions/definitions	Active shielding: creating specific selection environment for targeted innovations	Passive shielding: embedded in the pre-existing environment
<b>S&amp;T</b>	Research programmes; Journal; Conferences; Technical standards and infrastructural arrangement	Actively modifying the material environment, e.g. through changing technical standards, or strategic R&D investment	Fitting into the grid integration standards created by regime actors
<b>Policy</b>	Regulations, policy goals, guidance	New regulations or laws; Specific plans and targets/ policy goals	Fitting into the current regulations

<b>Socio-cognitive/ public &amp; culture</b>	Social norms; cultural significance; symbolic meaning; values	Deliberately creating new culture and values targeting the take-up of specific niche technologies; questioning regime conventions and debating the regime norms to enable diffusion of specific niches <sup>12</sup> (Smith et al., 2016)	Identify and fitting into pre-existing cultures and values
<b>Users/market</b>	Market rules and institutions, user practices and preferences	Creating new market rules and business models; user relationships	Seeking for different application domains; seeking users/consumers with different preferences
<b>Industry</b>	User–producer networks; industry routines; labour capabilities; organisational networks	Creating new industry actors; or empower new actors, e.g. farmers	Relying on the incubators from the incumbents which provide short-term protection

#### 4. 2. 2 Multiple scales of niche shielding dynamics

To address the question of when and how to phase out temporary protective space, it is crucial to recognise the multiple scales of shielding. Local shielding dynamics are shaped by strategic interventions not only from local actors but also from national and global actors. Moreover, the local selection environment is also shaped by selection pressure or the changing of niche–regime interactions on a national or global scale (Fünfschilling and Binz, 2018). For example, changing a national policy and market environment may shape the investment strategies of national or international investors in certain provinces, and thus shape the local niche shielding dynamics.

The multi-scale nature of niche shielding has been indicated by recent studies on the geography of sustainability transitions (Hansen and Coenen, 2015; Truffer et al., 2015). As argued by Raven et al. (2012), space and scale have always been implicitly indicated in transition studies, especially in the concept of niches. Regional and economic geography studies have argued that the interactions of actors and institutions on multiple spatial scales interact to create ‘spaces’ for the emergence of radical innovation (Boschma et al., 2017). Geels and Raven (2006) distinguished local projects from more general global socio-cognitive rules, i.e. niches. They argued that the accumulation of learning from local projects can contribute to global-level socio-cognitive niches. This ‘geographical lens’ enables the distinction between local learning and more general schema. Moreover, it offers spaces to examine how these multi-scale linkages and

<sup>12</sup> For niche development, it is not just about creating a new niche market, but also about changing the regime selection environment (which relates to empowering activities (Smith and Raven, 2012)), which enables niche shielding. This could be regarded as active shielding.

frictions enable or frustrate local niche development (Sengers and Raven, 2015). However, it is still unclear how the changing of niche–regime interactions at global and national scale may shape shielding dynamics at the local scale. Acknowledged in recent geographical studies of sustainability transitions, actors hold different resources and interests in the spatial variations of socio-technical structures across different geographical sites (Dewald and Truffer, 2012; Lawhon and Murphy, 2012; Truffer and Coenen, 2012). Thus, niche and regime actors may hold different interaction patterns across multiple scales (local, provincial, national and global level).

In summary, recent geography of sustainability transitions studies have advanced the understanding of the multiple scale nature of transition dynamics through incorporating insights from economic geography studies (Hansen and Coenen, 2015; Truffer et al., 2015). However, there is still limited understanding of how the interactions and linkages among these multiple scales shape niche shielding dynamics, and, especially, how niche shielding can be coordinated in multiple dimensions across multiple scales.

This paper therefore advances the understanding of shielding dynamics for niche development by examining wind power development in two of China's provinces. This focus complements existing transition studies in three ways: first, the cases focus on non-western/non-European countries. Second, the study systematically examines how niche shielding shifts across multiple dimensions of a socio-technical system; in particular, it examines how the shielding process unfolds to coordinate across these dimensions. This has been largely neglected in existing studies. Third, the cases focus on niche shielding at the provincial as well as the national scale. It thus develops a geographically sensitive lens to unfold niche shielding dynamics.

#### 4.3 Methodology and data collection

This study adopts a qualitative methodology, using case studies. The longitudinal case study has become a standard approach for tracing the process of socio-technical change to identify the underlying mechanisms and patterns (Grin et al., 2010; Smith et al., 2014). Following replication logics, it compares two contrasting cases to develop more comprehensive understanding of how niche shielding dynamics unfold (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Yin, 2014). To address the research question, it requires cases where the niche has been established. Moreover, the study requires longitudinal periods which enable the researcher to trace niche shielding dynamics over time (Pettigrew, 1990). To fulfil all these purposes, following paradigmatic case selection strategy proposed by Flyvbjerg (2006), this study investigates wind power development in two provinces of China – Inner Mongolia and Jiangsu as well as the

national development from 2000 until 2017. This focus enables a geographically sensitive understanding of how niche shielding dynamics unfold across multiple scales.

Wind power was selected because it is one of the most established renewable energies in China (Yang et al., 2020). It is increasingly competing with the coal power regime in China's electricity system. This is evidenced by the goals set up by Chinese central government that aim to achieve grid parity of onshore wind power with coal-fired power on the generation side by 2020 (NDRC, 2016). Wind power is China's second largest renewable energy (hydro power is in first place) and the third largest electric power in the country's electricity mix (around 5% in 2017). It took less than two decades for China to outpace other world leading countries to become the global leader of the wind power deployment market (see Figure 4.1). Inner Mongolia and Jiangsu province were chosen because of their contrasting wind power development and niche shielding dynamics (Yin, 2014). Inner Mongolia is leading the country's wind power development while Jiangsu has relatively moderate wind power development, despite its great protentional of electricity demand.

This study adopts process theory to trace the long-term change process to identify prominent patterns rather than arguing for simple explanations (Geels and Schot, 2010). It traces historical events to construct the storyline of niche shielding dynamics for wind power development. The analysis draws on several primary data sources, including interviews and a workshop, as well as secondary data. The interview data were collected at two different stages, from October 2017 to March 2018 and in January 2019. In the first stage, I conducted 30 semi-structured interviews with representatives from key stakeholders (see Appendix Table A.1). After each interview, I produced an English summary report. The second stage included four follow-up interviews to examine and re-check certain information. Each interview lasted around one hour. Most of the interviews were conducted in Mandarin, with two conducted in English. All of the interviews were audiotaped and then transcribed and translated.

Data from the interviews were used to identify key events and to develop the historical accounts of niche shielding for wind power development at the national level and in the two provinces. The interviewees were asked which were the key events, who were the main actors/drivers and what role did these main actors play during wind power development.

Data analysis involved several stages. First, I coded the interview summary reports to identify the key historical events and key stakeholders during the wind power development process in the two provinces and at national level. The interview data were complemented and triangulated through secondary data, including key policy documents, both national and from



the two provinces, academic articles in English and Chinese (largely from China's CNKI database), professional Chinese journals (e.g. <solar power>, <wind power>, <state grid>), organisational reports (e.g. reports from the national and provincial wind power and the electric power associations), and local and national news reports. This was followed by writing a case study report including the historical account of key events and key stakeholders at different stages for wind power development at the national level and two provinces.

A one-day workshop was conducted to examine the storyline presented in the case study report. The workshop was conducted in March 2018, at the end of the first stage of fieldwork, and was attended by 22 participants from different stakeholders. During the workshop, data was collected in different formats: facilitated focus group, lectures and session discussions.

The second stage of data analysis employed an open coding approach, as introduced by Blair (2015), to allow the emergence of certain patterns of how niche shielding evolves through a bottom-up approach. This open coding offers spaces to capture more empirical insights which may go beyond the prior theory. The insights that emerged from this process complemented the theoretical concepts and could alter the coding structures. During this stage, I identified the lack of coordination of shielding initiatives applied to different dimensions of the socio-technical system, and also across the provincial and national scale, which become crucial barriers for further wind power development. These features of empirical experience are crucial for the final conceptual framework adopted to examine niche shielding from the two proposed aspects: multiple dimensions and multiple scales. I then re-contextualised the identified historical events and niche shielding dynamics through analytical concepts and present the results in section 4.

#### 4. 4 Wind power development

In this section, I will introduce how niche shielding dynamics unfold for wind power development in two focal provinces as well as at the national scale.

##### 4. 4. 1 National level

Although China began piloting wind power for electricity in the 1970s (He and Shi, 2010), its installed capacity lagged behind other leading countries before 2006 (see Figure 4.1). The big leap in wind power installed capacity started in 2007 and the country has been leading the global market since 2010. Shielding against selection pressure from five dimensions enabled this rapid shift in the country's wind power installed capacity.

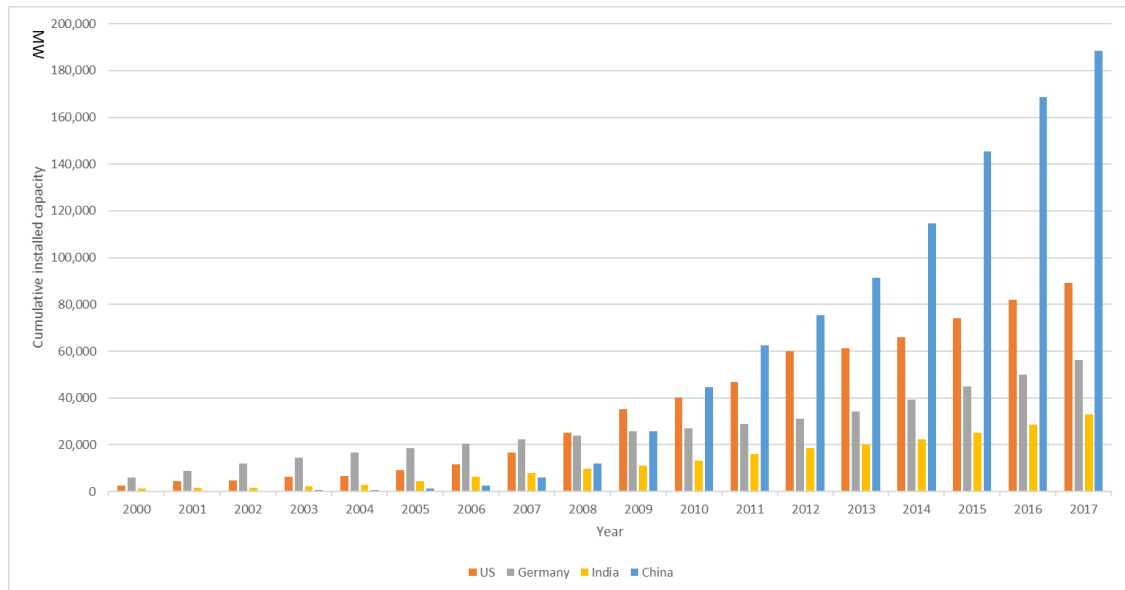


Figure 4.1. Cumulative installed capacity of wind power in US, Germany, India and China: 2000 to 2017  
Source: author's own, based on statistical data from Global Wind Energy Council

In the S&T dimension, China has rapidly caught up and its recent improved indigenous technological capability in the wind power manufacturing industry has been recognised (Ru et al., 2012; Gosens and Lu, 2013). In the 1990s the central government launched Ride the Wind programme to improve the domestic technological capability. To encourage domestic technology development, in 2002, the “State Tenth Five-Year Plan (2001-2005)” included a research project to perform R&D for a 750kW wind turbine unit. The companies Zhejiang Windey and Goldwind undertook the project and the result of their development was industrialised production in 2004. These projects accumulated valuable experience in exploring the localisation and commercialisation of wind turbines (He and Shi, 2010). National R&D programmes have contributed massively to improving the innovation capability of the country's wind power manufacturing industry (He, 2016).

In the industry dimension, the country has witnessed rapid development of the manufacturing industry since 2007. To develop and nurture domestic industry, in 2003, the Chinese government undertook concession projects to support the scale development of wind power. To improve industry capability, the concession projects required that the power plant farms should be at least above 100MW and at least 50% of the equipment should be produced domestically. The local content requirement was raised to 70% in 2005 (and later re-adjusted to 50% again). To effectively reduce the cost of wind turbines, the concession projects introduced a tender-based market mechanism. Investors submit bids specifying the lowest price at which they were prepared to supply electricity to the grid. The government's commitment was to buy electricity from a chosen operator at the price quoted in the bid (Liu and Kokko, 2010). The first

concession project in 2003 had led to only 200MW installed capacity. This new bidding mechanism, which aimed to reduce the cost of wind farms, led to the investors rushing to bid for regions with good wind resources (interview, director of China Wind power industry association, 2017). In 2009, the central government positioned the wind power industry as the strategic emerging industry, one of the engines for China's future green economy growth (Yang et al., 2020). This further set the legitimacy for the local support for wind power manufacturing industry.

In the policy dimension, the policy environment for wind power was fragmented and uncertain before 2002 (Lema and Ruby, 2007; Liu and Kokko, 2010). Since 2006, the country has formulated a comprehensive policy environment for wind power. A set of policies was implemented to nurture domestic wind power deployment after the national "Renewable Energy Law" was issued in 2005). The "Renewable Energy Law" regards the development of renewable energy as the priority area for future energy development, providing a clear and positive vision for wind power development in China (Wang et al., 2012). Following this law, various detailed policies and measures were implemented; for example, in 2006, the "Special Renewable Energy Fund", the "Regulation of Renewable Energy Generation", and the "Renewable Energy Price and Cost-Sharing Management" were drafted, which provided a positive policy environment for the development of renewable energy. Moreover, in 2007, the central government issued "Medium and Long-term Development Plan for Renewable Energy" and it set up the overall targets for wind power development in the country's energy portfolio.

In the market dimension, the early deployment of wind power was mainly off-grid small-scale wind turbines in remote areas lacking access to the grid infrastructures (Liu et al., 2002). However, from 2003 the market shifted towards large-scale wind farms after the central government implemented concession projects. In 2007, the central government introduced the mandatory market for RE in the "Renewable Energy Medium-Long Term Development Plan". The Plan required the traditional electric power generators to hold 3% of non-hydro RE by 2010, and 8% of non-hydro RE by 2020. Power companies are compelled to produce wind power while grid companies are compelled to buy it (Lema and Ruby, 2007; Wang, 2010). It has been recognised that this mandatory quota policy has played a crucial role in compelling the conventional power generators to invest in large-scale wind power plants (Zhu et al., 2019). To further stimulate the domestic market for wind power industry development, in 2008, the central government advocated building large-scale wind farms to integrate into the super-grids. This initiative proposed to build seven mega wind power sites in China (including in Inner Mongolia and Jiangsu province) to forge the "wind power Three Gorges (large scale wind farm

sites)". In 2009, the National Energy Administration set up feed-in tariff support for wind power development in China.

Since 2012, with the rapidly increasing installed capacity of wind power in China, high curtailment rates became a prominent issue in the northern part of China (especially in the provinces of Gansu and Inner Mongolia) (see Figure 4.2). This dramatically shaped further wind power deployment in the country. The investors perceived onshore wind power development had peaked because of the high curtailment rates, and they started to invest strategically towards the regions with low-speed wind and offshore wind farms which had been perceived as a potentially large market (interview, director of China wind power industry association, 2017).

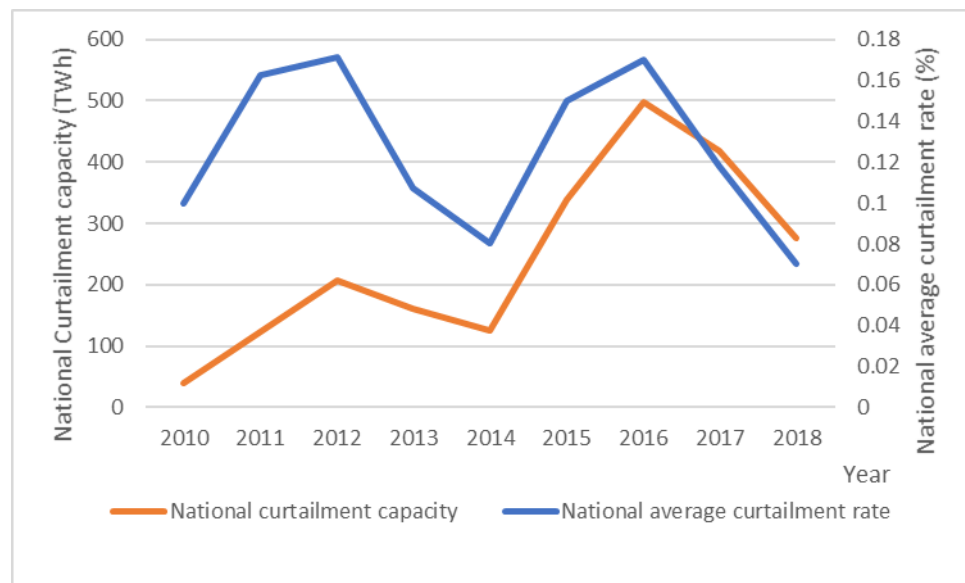


Figure 4.2. 2011-2018 Curtailment capacity of wind power in China  
Source: author's own, based on statistical data from National Energy Administration

In 2016, the National Energy Administration issued the "13th Five-Year Plan for Wind Power Development (2016–2020)", which put forward that in total, on-grid installed capacity of wind power should reach 0.21 billion kW and above, and that the generation from wind power should reach 420 billion kWh, contributing 6% of the whole of society consumption of electricity. It was the first time that the whole society electricity consumption proportion was used as the indicator for the deployment scales of wind power in China. Previously, installed capacity had been the only indicator (interview, Secretary-general of wind power industry association, 2017). This could be seen as evidence that the central government was seeking to support wind power not only for industrial development but also for green electricity generation. Meanwhile, it made an ambitious plan for onshore wind power to achieve grid parity without subsidies (i.e. competitive to the on-grid price of coal-fired power) in 2020. To achieve this goal, several experiments have been conducted to identify local institutional barriers. For example, to

guarantee its dispatching priority the central government urged the local governments to cancel planning-based generation quotas step-by-step (IEA, 2019).

#### 4. 4. 2 Inner Mongolia

Located in the northern part of China, Inner Mongolia has above average GDP per capita. It has historically been one of the crucial energy suppliers for the whole country (Kwan, 2010). As the largest coal supplier in China, it provided a quarter of the whole country's total coal production in 2016 (Kargbo, 2017). Meanwhile, Inner Mongolia is leading China's fast deployment of wind power (Zeng et al., 2014). By the end of 2017, its wind power generation contributed 12.45% of the province's total electricity generation mix while coal power, solar power and hydro power contributed 84.47%, 2.55% and 0.53% respectively (data from Inner Mongolia Electric Power Association).

In the S&T dimension, Inner Mongolia has been leading the country's wind power exploration since the 1970s (Han et al., 2009). Early local wind power experimentations focused on small wind turbines for electricity based on the local researchers' interests and their beliefs that wind power could be utilised to supply electricity for local demand (interview, Secretary-general of wind power industry association, 2017). In particular, wind power was perceived as a potential solution to electricity supply problems for herdsman, who did not have access to the electricity grid (Zhang et al., 1999). Off-grid small-scale wind turbines met the need of the herdsman who were geographically dispersed and generally moved around during the year. Since the 1980s, wind power was seen as part of the province's strategic development plan. Local officials started to provide support for wind power R&D. In 1987, the Ximeng wind power exploitation research institute was founded, aiming to exploit the local wind resource endowment and the exploitation of wind power for electricity (interview, Secretary-general of wind power industry association, 2017). The local demand for electricity promoted local R&D investment in small-scale wind turbines.

In the market dimension, since 2006 Inner Mongolia has been perceived by national and international wind power investors as a perfect site for wind power deployment. After 2007, especially, the western part of Inner Mongolia was designated as one of the national "wind power Three Gorges" initiatives, it further attracted large state-owned enterprises to invest heavily in building large-scale wind farms in the province. Inner Mongolia was perceived as one of the most advantageous sites for wind power because of its high wind resource endowment, advanced grid infrastructures and supportive local government policies (Han et al., 2009). Inner Mongolia municipal governments also actively set up local development plans and provided supportive guidance with, for example, income tax revenues supporting local renewable energy

development (Cherni and Kentish, 2007; Liu and Kokko, 2010). Since 2008, wind power witnessed rapid deployment in Inner Mongolia, leading the installed capacity across the whole country.

In 2011, Inner Mongolia started to suffer high curtailment rates of wind power. To improve generation, the local government encouraged wind power generators to sign an agreement directly with large consumers to encourage direct trade between the generators and the users. At the same time, other market mechanisms were also explored by local government. For example, dispatching mechanisms were changed, and the priorities were largely given to RE. To encourage support from thermal power generators, the Inner Mongolia government created the capacity and auxiliary service market to encourage the retrofit of local thermal power plants for flexibility. The thermal power generators could benefit from providing services for the wind power through the ancillary service market. In 2012, to solve the high curtailment issues, the local government encouraged the direct trading of the generation quota between the thermal power generators and wind power generators, which was perceived as a policy aiming to reduce the generation hours from thermal power while improving the generation from wind power. However, this local experimentation was suspended by a central government ruling that this practice was illegal.

To improve the direct competitive advantages of wind power over thermal power, the province launched local experimental projects to achieve subsidy-free wind farms after the central government decided to cancel the subsidy for onshore wind power by 2020. Inner Mongolia is planning to build 6GW wind power farms to fuel the winter Olympic games (to be held in 2022) without any subsidy. This local experimentation serves to identify the institutional barriers for wind power farms to achieve subsidy-free market competitive advantages. Moreover, there are local experimentations implemented to utilise wind power for heating. During the winter, there is a high demand for heating in Inner Mongolia, while the increasing penetration of the combined heat and power (CHP) plants has largely reduced the generation of wind power there (Liu et al., 2013).

However, there is a lack of incentives for grid companies to put in place shielding for niche development, which has further constrained wind power development. This is illustrated in the following quote from the 2018 workshop:

Since 2008, both the central and local government have mobilised insufficient market incentives for grid companies. The short-sighted plan aiming to pursue economic scales of large-scale wind power deployment to promote domestic manufacturing industry capability exacerbated the divergence between the wind power instalment and the

electricity generation, evidenced by the increasingly high curtailment rate since 2012. This has further constrained the rapid deployment of wind power and the system transition in Inner Mongolia (Workshop participant, 2018).

#### 4. 4. 3 Jiangsu province

Located on the eastern coast of China, Jiangsu is one of the country's leading economically developed provinces (ranking 4th in GDP per capita after Beijing, Shanghai and Tianjin). Before 2012, with its rapid economic growth, Jiangsu used to suffer from considerable energy shortages. In 2004, Jiangsu province had a power shortage of about 8,060MW, which accounted for about 25% of its total electric load in that year (Zhao et al., 2009). Since then, Jiangsu province has experienced a rapid increase of installed capacity of power plants, mainly coal powered. Now the province has sufficient capacity of local installed electric power plants. The energy consumption structure in Jiangsu province is heavily based on fossil fuel but recently it has largely adopted renewable energy, mainly wind and solar power, to fulfil its continuously increasing electricity demand. In 2016, RE contributed 8.3% of its total energy mix, increasing to 9.4% in 2017. According to its 13<sup>th</sup> Five-Year-Plan for Energy Development (2016–2020), Jiangsu province aims to achieve 11% of non-fossil fuel in its energy mix by 2020 (Jiangsu Provincial Government, 2017). With its scarcity of fossil fuel (coal, oil, natural gas) and hydropower resources, it has to import energy from other provinces, making it one of China's typical energy-importing provinces (Yan et al., 2007). However, in recent years, the deployment of renewable energy has offered an opportunity for the province to increase its self-reliance in energy.

In the market dimension, despite of its huge local electricity demand, the development of wind power in Jiangsu province was slow before 2012 (Zhao et al., 2009). Investors had limited motivation to invest there and the province was perceived as a region with limited onshore wind resources (interview, Secretary-general of Jiangsu Renewable Energy Industry Association, 2017). Although local electricity demand is anticipated to continue to grow in the Jiangsu province; it mostly relies on coal power, and about 80% of the coal consumed is imported from outside the province (He et al., 2016). In 2016, Jiangsu provincial government enacted the 263 Action Plan for ecological conservation. The Action Plan aims to improve local air quality and set strict targets for reducing local coal consumption. To achieve this target, as an energy importer, it relies on the clean electricity transmitted from other provinces, mainly the RE from Inner Mongolia and Shanxi province. Recent years have gradually seen Jiangsu province increasing its onshore wind power capacity.

With the increasing curtailment rates in the three northern regions of China, instalment of wind power has shifted towards the central and southern regions of China, which are characterised by low speed and poorer wind resources. The strong electricity market and the improved

electricity capacity started to attract investors. Against this background, Jiangsu was regarded as one of the most promising provinces which could achieve a large proportion of RE in the near future. The ambitious goal is 50% RE in its generation mix by 2050 (Greenpeace, 2015). There has not been any wind curtailment in Jiangsu province, where renewable energy has been 100% absorbed in the provincial grid. Wind power utilisation hours in Jiangsu reached 2,100, which is close to the levels in Europe and USA.

In the policy dimension, local policies for wind power deployment in Jiangsu province were fragmented, conservative and often short-term before 2012 (Hong et al., 2013). Since 2006, offshore wind has been part of the local government's strategic plans to build "Three Gorges offshore wind" (large-scale offshore wind farms). In 2012, it set targets for local wind power installed capacity to reach 6GW by 2015 and 10GW by 2020. This strategic plan matches wind power investors' perceptions as they started to pursue offshore wind as a large potential market. "Wind power investors started to assume that onshore wind power development is saturated/has peaked because of the high curtailment issues" (interview, Jiangsu wind power industry association, 2017). Jiangsu province began marketing itself as the place for developing offshore wind power market in China.

Through the provincial 12th Five-Year Plan (2011–2015), Jiangsu province implemented holistic policy plans to emphasise the strategic role of increasing renewable energy and improving energy efficiency for addressing climate change. It set a goal to increase the proportion of non-fossil fuels from 21% in 2011 to 30% by 2015. In the provincial 13th Five-Year Plan for the Development of Strategic Emerging Industries, Jiangsu province regarded wind power as a strategic emerging industry, emphasising the province's leading position in the wind power industry. It set a goal of non-fossil fuel energy contributing 11% to its total energy mix, and the non-hydro RE should contribute 7% to the electricity mix by 2020. However, some interviewees suggested that the goal is not very ambitious considering that in 2016 it was already 6.13% (interview, Jiangsu renewable energy industry association, 2017).

In the industry dimension, to promote its local wind power manufacturing industry, the local government adopted the strategy of "resource exchange for industry" to attract investors to bring in the local wind power manufacturing industry if they preferred to invest into local power plants (Shen, 2017; Shen and Xie, 2018). Several regional wind power industry clusters were established during this period. Coastal areas in Jiangsu province are lagging behind other regions in the province in economic growth (He et al., 2016). Since 2012, they have regarded the development of wind power as an opportunity for their economic development, to improve local employment, and to build up the local manufacturing industry capability. These regions' local



governments largely promote the building of local wind power industry clusters (He et al., 2016). Meanwhile, the local government and local grid company largely invest to improve the local grid capacity. They update the grid integration plans each year, to ensure the integration of wind power into the grid (Three-year development plans for energy development of the coastal regions in Jiangsu province, 2009).

Since 2016, the local grid company in Jiangsu province has been experimenting with different technologies and models to support distributed energy development. As one of the leading areas for the development of smart grids and micro-grids, the province is proactively promoting local experimentations, including building the country's largest integrated energy system to integrate RE in the local electricity system. The emergence of a distributed energy system can potentially provide opportunities for the province's development of small-scale distributed wind energy. Jiangsu province has been historically relying on energy imports from other regions. The deployment of local renewable energy power plants provides the local momentum to pursue energy self-sufficiency based on local resources. However, this strategy to develop a distributed and integrated energy system would not necessarily directly contribute to the large scale-up of installed wind power capacity.

#### 4. 5 Discussion

Here I will first discuss how niche shielding dynamics unfold in the two cases from the two aspects of multiple dimensions and multiple scales. I will then compare across cases to generate insights on the question of how niche and regime actors interact to shape these shielding dynamics.

##### 4. 5. 1 Niche shielding dynamics across multiple dimensions and multiple scales

Successful development of radical innovations requires niche shielding to hold off selection pressure not only within S&T but also in the market, culture, policy and industry, the five dimensions of the socio-technical system. Shielding that focuses narrowly on only some dimensions and without consideration of coordination among all five dimensions may constrain niche development.

This has been evidenced by the contrasting outcome of wind power development in two provinces. Although the provinces are both listed as priority sites for large wind power farms by the central government, Inner Mongolia built capacity quickly while Jiangsu province was a laggard. This divergent deployment of wind power in these two provinces reflects the different local shielding dynamics. The local selection environment, such as the local resource endowment, local potential electricity market, local grid infrastructure and local policy

environment, largely shaped wind power development in these two provinces. As illustrated in Figure 4.3 there was wider shielding observed in the case of Inner Mongolia compared with Jiangsu province. Both active and passive shielding across all five dimensions generates favourable protective spaces in Inner Mongolia, whereas in Jiangsu the shielding narrowly focuses on the S&T and industry dimensions. The lack of supportive local policies and wind power investors' perceptions of limited wind resources in Jiangsu have been the main barriers for the province's wind power development in the early stage. Moreover, the less active role of local government in Jiangsu province constrained the rapid deployment of wind power in the province. For example, after the Renewable Energy Law was introduced in 2005, Inner Mongolia's local government was very active in promoting local wind power development because of its potential for supporting local economic development (Li et al., 2009), while in contrast during the same period, the Jiangsu provincial government was less active in providing supportive policy.

Niche shielding dynamics at national level also support the argument that coordination among the different dimensions is key for successful niche development. The country's early stage niche protection for wind power development focused narrowly on nurturing the domestic market for industry development while insufficiently coordinating with shielding in the market dimension. This has further constrained wind power development with its high curtailment rates (Zhao et al., 2016). This is illustrated by Li et al. (2009):

For a long time, there is a tendency that China pays more attention to power installation capacity than power generation capacity and efficiency in the market. In all plans and statistics, there is always data of wind power installed capacity, but no clear data on the level of wind power generation (p. 21).

As a result of the lack of attention to wind power generation, the utilisation of installed wind power is very low compared to other countries such as the USA (Ye et al., 2018). It has thus caused considerable economic waste, which undermines the investment incentives from power generators. This point supports the argument that coordination across different dimensions is crucial for successful niche development.

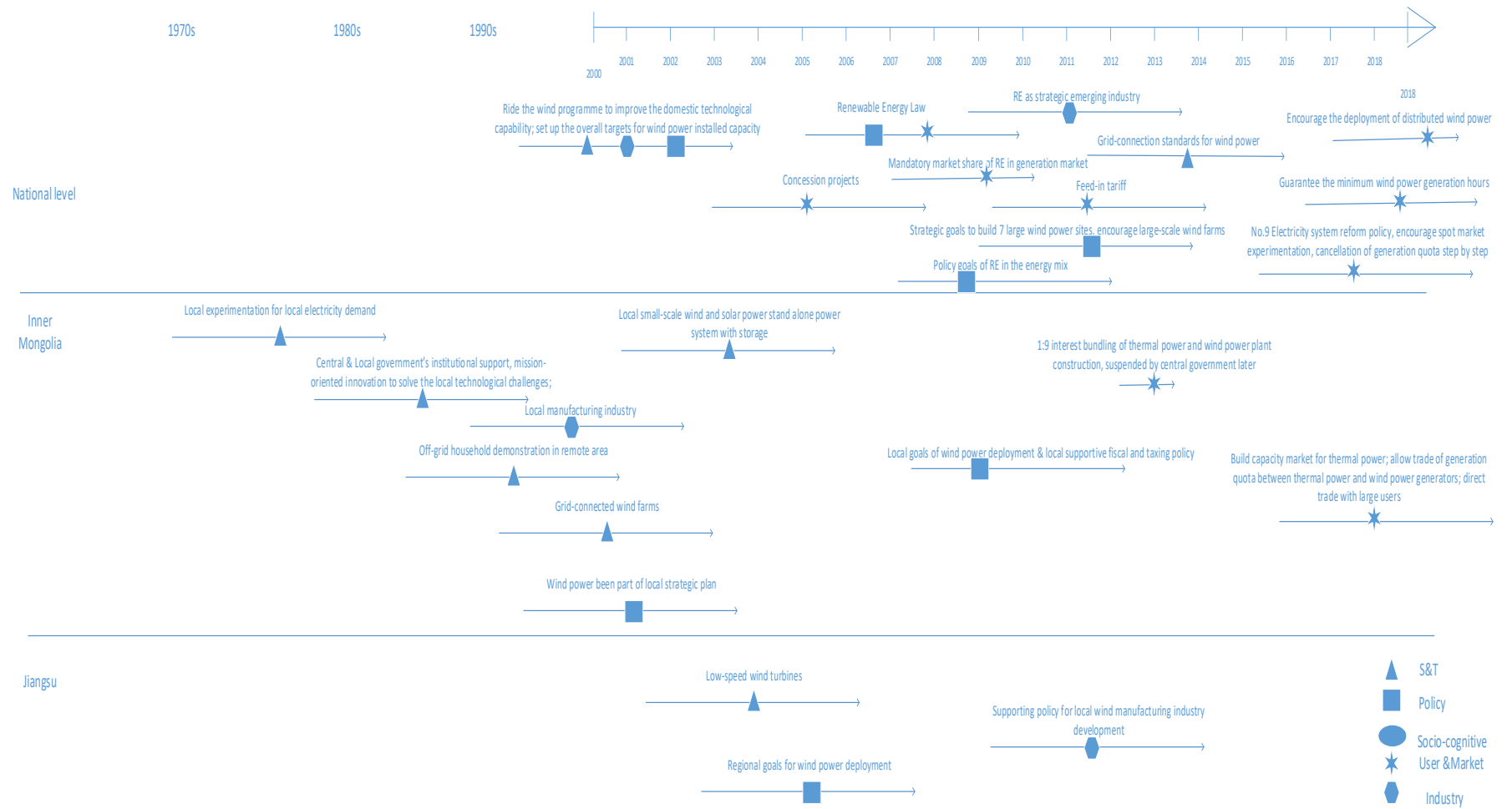


Figure 4.3. Shielding dynamics for wind power development at national level and in Inner Mongolia and Jiangsu province

Having discussed how the divergent local shielding dynamics shaped different wind power development in two provinces, I now argue that wind power development in the two provinces is also shaped by national shielding dynamics. Wind power development in the two provinces is largely influenced by the national selection environment, such as wind power technology performance, industry development, policy environment, electricity market, culture and social values. The success of Inner Mongolia can attribute to the proactive role of local actors, together with national and international large wind power investors (Li et al., 2009). During the early 2000s, both national and international wind power investors perceived Inner Mongolia as the perfect site for large-scale wind power plants because of its good wind resource endowment (Li et al., 2007a). This is in contrast to Jiangsu, which had been perceived as having limited wind power resources and being unfit for the development of wind power plants. The contrasting perceptions from investors are largely responsible for their divergent actions in investing in wind power development in the two provinces. In Jiangsu, the early take-up of wind power was largely driven by the concession projects implemented by the central government. After 2012, take-up was shaped by the changing market at the national level. When wind power experienced high curtailment in the regions with good resource endowment, wind power investors largely pursued their investment in Jiangsu, where there were good grid integration conditions. The changing perceptions of investors who shifted their geographical preferences from regions with good resources towards to regions with good electricity markets and the potential for grid integration have shaped niche shielding dynamics in the two cases. Overall, local wind power deployment is largely shaped by the changes of selection environment at the national scale.

#### 4. 5. 2 Implications for niche and regime actors interaction dynamics

Based on the above discussion, I argue that the interaction between niche and regime actors is complex, going beyond to the conventional understanding of niche actors substituting regime actors or regime actors going against niche actors. To unpack the interaction dynamics between niche and regime actors, it is crucial to examine how they interact across multiple dimensions and across multiple scales.

The two cases indicate that niche and regime actors may align in certain dimensions while come to conflict in other dimensions across multiple scales. As in the case of Inner Mongolia, although the central government stipulated the dispatching priority of renewable energy, urging the grid company to purchase all generated renewable energy, due to lack of both local political and economic incentives, the local grid company followed the local government's plan to give priority to dispatching thermal power. To ensure the safety of electricity system and security of supply, at the beginning of the year, the local government issues an annual quota-based

electricity generation plan which guides the dispatching activities of the local grid company. The plan sets out the quota of dispatching hours of thermal power to guarantee the supply of electricity. This has constrained the system transformation and slowed wind power development in Inner Mongolia (Zeng et al., 2016). This case indicates that there is a lack of coordination between niche and regime actors across the provincial and national scales. While in the case of Jiangsu province, the provincial government has been intensively pursuing local wind power manufacturing development while prioritising the dispatching of thermal power in the generation market. This indicates that niche and regime actors can align in the industry dimension while come to conflict in the market dimension.

#### 4.6 Conclusion

To conclude, this paper contests the conventional understanding of niche development as a linear process of creating niche protective spaces and which are then phased out. The understanding of niche construction as a process of phasing out protective spaces step-by-step is misleading. This paper provided a novel framework to examine niche shielding dynamics from two crucial aspects: (i) how niche shielding shifts across multiple dimensions of the socio-technical system; and (ii) how niche shielding unfolds across multiple scales. It has examined the historical development of wind power in two of China's provinces as well as at the national level. This has crucial implications to unpack the interaction dynamics between niche and regime actors for niche development. Following the two aspects of niche shielding dynamics, the research findings suggest niche and regime actors may coordinate in some dimensions while conflict in other dimensions of socio-technical system across multiple scales. Overall, this paper argues for a complex system understanding of how niche and regime actors interact to shape niche development.

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## Chapter 5 Article 3

**Shaping the directionality of sustainability transitions:  
The diverging development patterns of solar PV in two Chinese  
provinces**

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## Abstract

A limited set of studies have addressed how actors shape the directionality of sustainability transitions. Building on recent institutional work literature, this paper explores how specific institutional activities developed by both niche and regime actors across spatial levels shape the directions of transition. We examine two cases with contrasting directionalities: solar PV in the provinces of Inner Mongolia and Jiangsu, both located in China. The former developed PV as part of the large-scale centralised power system and the latter focused on PV development as a core element of an alternative distributed form of power generation. We investigate provincial differences as well as the state-provincial dynamics. The paper therefore develops a multi-scalar understanding of institutional work. Our research findings suggest three aspects have been key for understanding the divergent patterns: the specific portfolio of enacted institutional work, the type of interactions between niche and regime actors and the selective leveraging of national institutional conditions by provincial actors. Based on these findings we formulate four propositions and propose a novel conceptual framework to investigate how actors shape the directionality of sustainability transitions.

**Keywords:** Actors; Institutional work; Directionality; Sustainability transitions; Solar PV development

## Highlights:

- Investigate the proactive role of actors in shaping provincial differences and the state-provincial dynamics of solar PV development in China from 2000 to 2018;
- We develop the concept of multi-scalar institutional work;
- Systematically assess how niche and regime actors adopt a multiplicity of institutional work strategies to shape divergent directions of transition;
- We formulate four propositions and propose a novel conceptual framework;
- Actors adopt institutional work not just across niche and regime boundaries but also across spatial levels (provincial, national, global level).



## 5. 1 Introduction

The development and scaling of renewable energy technologies is one of the major success stories in terms of decarbonising the electricity sectors. Solar photovoltaics (PV) are a major case in point. Generation costs per KWh decreased by more than 95% since the 1970s (Kavlak et al., 2018), which makes it a cost-competitive alternative in many application contexts today, and has led to a large scale of diffusion of solar PV over the last decade (SolarPower Europe, 2018). However, despite the success of this technology, the ultimate impact on the structure of the electricity sector remains unclear. Will solar just be an additional source of energy in an otherwise unchanged centralised electricity system or will the diffusion of solar lead to a fundamental restructuring of the sector towards more decentralised power generation with new grids, business models and use patterns? This is a question about the directionality of the transition.

In this paper we explore the issue how actors try to shape the directionality of the transition in one of these two ways. Following the Multi-Level- Perspective (MLP) understanding in the sustainability transitions literature we conceptualise the electricity sector as a socio-technical system (Jacobsson and Bergek, 2004), which is characterised by a very clearly elaborated socio-technical regime of rules, such as norms, regulations and cognitive beliefs. Because of this emphasis on rules sustainability transitions can be seen as an institutionalisation process (Rip, 1992; Rip and Kemp, 1998; Geels, 2004; Fünfschilling and Truffer, 2014). New technological alternatives --such as solar PV has to accommodate to these existing rules, this may hamper their development prospects substantially. The MLP assumes that early technological development depends on the availability of “protective spaces” so-called niches in which the necessary learning and alignment processes can be tried out and tested before an alternative can scale up and perhaps challenge the predominant technologies (Hoogma et al., 2002; Schot and Geels, 2008). Essentially, promoters of niches have two options for dealing with prevailing regime rules: they either adapt to the given situation or they proactively try to change the rules in a way that accommodates for the specificities of the new option. Smith and Raven (2012) classified these two approaches as fit-and-conform and stretch-and-transform patterns of transformation. Our research questions are formulated as follows: what kind of strategies do actors enact in order to support either of the two development patterns? What kind of institutional conditions do they have to mobilise and which kind of cooperation do they have to engage in?

Battles over the directionality of transition are not free of conflicts, because unavoidably they will challenge the dominant position of incumbent companies and enable new actors to

influence the future development of the socio-technical system. The transition studies literature has accumulated a sizeable stock of evidence on how existing regimes resist transformative pressures and how difficult it is for niches to grow and transform the prevailing rules (Markard et al., 2012). The question of how actors try to shape the directionality of the transition has much less been analysed. Our point of entry for answering this question build on insights from recent studies on “institutional work” (Lawrence and Suddaby, 2006). This literature conceptualises institutional change as the outcome of actors’ attempts to maintain, create or disrupt institutions (Lawrence et al., 2009). Recently, several studies have started to show how concepts of institutional work may be fruitful for analysing sustainability transitions (Brown et al., 2013; Binz et al., 2016; Fünfschilling and Truffer, 2016).

We will build on these recent insights but extend them in important respects in order to address questions of directionality: First, we do not assume that most of the transformative institutional work is carried out by niche actors, leaving regime actors in an essentially defensive position. We therefore adopt an open attitude regarding the portfolios of institutional work different actors employ, irrespective of their degree of incumbency. Second, and as a consequence, we want to explicitly consider the kind of relationships that are established between incumbents and new entrants in support of either of the development patterns. And third, given that institutional structures are defined at different levels of jurisdictions, we propose to analyse institutional work as strategies that may operate at and across different spatial scales.

To answer our research question, we choose a revealing case (Yin, 2014) of the differential deployment of solar PV in two Chinese provinces, Inner Mongolia and Jiangsu. Significant solar development happened in both provinces. But their directions differed substantially. Inner Mongolia implemented a large-scale centralised approach to connect solar power to the electricity grid – thus exemplifying a fit-and-conform pattern, while Jiangsu became a leader in distributed solar PV systems, building on a large range of local experiments and supporting institutions, thus more resembling the stretch-and-transform pattern. This divergence of development patterns occurred despite the seemingly disciplining national framework of Chinese industrial policy that applies to both provinces in an equal manner. We would therefore expect to find substantial and different instances of institutional work employed by local actors in these two provinces that can explain the divergent patterns. Both provinces may have a divergent starting position in terms of urbanisation, industrialisation, population density that may be looked at to explain the divergence. Our assumption is, however, that these factors operate as distinct cause that can be mobilised in different ways through institutional work. It is this work we see as the immediate cause of the divergent patterns.

The paper is structured as follows. Section 2 introduces the literature on institutional work and discusses how questions of directionality can be addressed in the analysis of sustainability transitions. Three core aspects are elaborated: i) portfolios of institutional work; ii) interactions between niche and regime actors; iii) the multi-scalar dimension of institutional work. Section 3 describes the methodology. Section 4 elaborates on the institutional work actors adopted to shape China's solar PV development in the two focal provinces as well as at the national level. Section 5 discusses how local actors performed institutional work to shape the respective development trajectories in the two provinces. Section 6 draws implication of this research for how directionality could be addressed in future transition studies.

## 5. 2 Institutional work and directionality

There have been different perspectives on why radical socio-technical change occurs. Some have argued that radical change in the socio-technical configuration of sectors can be triggered by extreme events like wars or environmental jolts (Sine and David, 2003). This “punctuated equilibrium” perspective argues that the system generally exists in a relatively static equilibrium (Werbelloff et al., 2016), which can only be changed through a strong and sudden shock (Gersick, 1991). In this view socio-technical change is treated as a black box, it is largely a result of external stimuli (Markard and Truffer, 2006). This view has always been criticised in sustainability transitions studies. It is seen as “probably only accurate for a few potential transition trajectories” (Fünfschilling and Truffer, 2016, p. 298). Most of the system transformation processes are driven by a combination of exogenous and endogenous driving forces (Geels and Schot, 2007).

Moreover, the external shocks “do not mechanically impact niches and regimes, but need to be perceived and translated by actors to exert influence” (Geels and Schot, 2007, p. 404). The actual directions of change are therefore shaped by actors’ strategies, which are guided by their specific interests and visions (Smith et al., 2005; Yap and Truffer, 2019). This implies attention needs to be paid to the endogenous and gradual transformation process taking place within the socio-technical system through strategic agency (Markard and Truffer, 2008; Pacheco et al., 2010; Smith et al., 2010; Grillitsch et al., 2018; Yap and Truffer, 2019).

Although a handful of studies have conceptualised how the interaction between exogenous and endogenous change processes produce different transition patterns (Smith et al., 2005; Geels and Schot, 2007), there is still limited understanding on the role of agency in shaping specific socio-technical transformations (Smith and Stirling, 2010; Grin et al., 2011). Farla et al. (2012) and Smith and Raven (2012) suggest to draw upon institutional scholarship to fill this gap.

The criticism that it remains unclear how institutional change happens resonates with developments in neo-institutional studies. Before 1990s, traditional institutional theory predominately treated institutions as relatively passive structures guiding the actions of actors (Meyer, 1982). Hence, they generally treated institutional change as a black box. Neo-institutional scholars, however, regard institutional change as the outcome of actors' attempt to intentionally reproduce, alter or destroy institutions (Battilana et al., 2009). Lawrence and Suddaby (2006) introduced the concept of 'institutional work' to explore the proactive role of actors in shaping institutional change. In our view, institutional work is better suited to study socio-technical transformations compared to the related concept of institutional entrepreneurship (Battilana et al., 2009), because it is less associated with a hyper-muscular view on actors' capabilities and acknowledges that institutional change is always a joint societal process where most actors have only limited effectiveness (Fünfschilling and Truffer, 2016). However, in actual applications to socio-technical transitions (see for instance Yap and Truffer (2019)), there is often only a small difference between the two approaches.

Institutional work conceptualises how actors purposively engage (individually and collectively) in an effort to prevent or generate institutional change. Lawrence and Suddaby (2006) categorise three strategies of institutional work actors can engage in: keep institutions alive (maintenance in the regime), change them (disruption of the regime) or create new ones (built-up niches and reconfiguration of socio-technical elements for new technologies). These three mechanisms are also reflected in sustainability transitions research, where regime actors are conceptualised as primarily busy with reproducing the regime in order to *maintain* their vested interests (Hensmans, 2003; Maguire and Hardy, 2009; Geels, 2014; Hess, 2014; Smink et al., 2015b; Ting and Byrne, 2020). Niche actors in contrast endeavour to *create* new institutions by setting up protective spaces that enable the maturing and scaling of their preferred alternatives (Geels, 2004; Seyfang and Haxeltine, 2012; Geels et al., 2016). Recent transition studies started to articulate the crucial role of *disrupting* institutional work by actors who aim at the destabilisation of the regime in order to shape the direction of transition (Brown et al., 2013; Kivimaa, 2014; Kivimaa and Kern, 2016).

The three type of strategies can be detailed further. Lawrence and Suddaby (2006) proposed a list of eighteen forms of work by which actors can influence institutions. Drawing on the work of Scott (1995) we group them by how prominently they address the regulative, normative or cognitive pillar respectively (see Table 5.1). Regulative pillar refers to formal rules, such as laws, government policies. Normative rules refer to values and social norms. Cognitive rules refer to the beliefs and symbolic meanings (Scott, 2001). We can take from the literature that

mechanisms of creating institutions, include advocacy, defining, and vesting. This “reflects overtly political work in which actors reconstruct rules, property rights and boundaries that define access to material resources” (Lawrence and Suddaby, 2006). They therefore contribute primarily to the build-up of regulative rules. Constructing identities, normative networks and changing normative associations emphasises “actions in which actors’ belief systems are reconfigured” and therefore address primarily the normative pillar. And finally, mimicry, theorising, educating alter the meanings and things taken for granted, and therefore address primarily cognitive rules. For lack of space, we are not in a position to offer detailed description of the different forms of institutional work. The reader is referred to Lawrence and Suddaby (2006) and Fünfschilling and Truffer (2016) for further elaborations (see also Table 5.1).

For the purpose of our analysis, we want to make two points here: i) we expect not all the listed forms of institutional work in Table 5.1 need to be performed during the process of sustainability transition. For the specific directions of sustainability transition, specific combinations of different forms of institutional work may be needed (creating, maintaining and disrupting) across three institutional pillars (cognitive, normative and regulative); ii) these three institutional pillars generally align with each other to maintain resilient social-technical structures (Geels, 2004). However, when shifts occur in one of these institutional pillars, it may create windows of opportunity for changes in other pillars too and thus more radical institutional change is likely to result.

We propose to call specific combination of different forms of institutional work a portfolio. Our assumption is that if actors, through such portfolio of institutional work, shape all three institutional pillars substantially, change will be more radical, e.g. rather support stretch-and-transform patterns. This has been argued by Ghosh and Schot (2019), who differentiate three transition pathways based on the divergent reconfigurations of the socio-technical dimensions and portfolios of changes in the different institutional pillars. They assume more diversified and integrated changes of different institutional pillars led to more fundamental reconfiguration of the socio-technical system, i.e., more radical transition pathways (also indicated by Geels and Schot (2007) and Kemp and van Lente (2011)).

Recently several further empirical studies have been conducted in the sustainability transitions field to explore the relevance of institutional work in order to explore how actors proactively build niches (Brown et al., 2013), or direct the course of socio-technical regime change (Fünfschilling and Truffer, 2016). However, these studies either focus on the historical reconstruction of singular socio-technical system transitions (Brown et al., 2013; Fünfschilling and Truffer, 2016; Novalia et al., 2018) or they focus on institutional work towards specific types

of institutional change (for example, towards technology legitimacy (Binz et al., 2016) or policy change (Hess, 2014)). There has been less attention on which actors are doing which type of institutional work, and how this influences the directionality of sustainability transitions.

Table 5.1. Mechanisms of institutional work shaping different pillars of institutions  
Adapted from Lawrence and Suddaby (2006)

<i>Pillars of institutions</i>	<i>Creating institutions</i>		<i>Maintaining institutions</i>		<i>Disrupting institutions</i>	
	Forms of institutional work	Definition	Forms of institutional work	Definition	Forms of institutional work	Definition
<i>Regulative</i>	Advocacy	The mobilisation of political and regulatory support through direct and deliberate techniques of social suasion	Enabling work	The creation of rules that facilitate, supplement and support institutions, such as the creation of authorizing agents or diverting resources;	Disconnecting sanctions	Working through state apparatus to disconnect rewards and sanctions from some set of practices, technologies or rules
	Defining	The construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies within a field;	Policing	Ensuring compliance through enforcement, auditing and monitoring		
	Vesting	The creation of rule structures that confer property rights	Deterring	Establishing coercive barriers to institutional change		
<i>Normative</i>	Constructing identities	Defining the relationship between an actor and the field in which that actor operates	Valorising and demonizing	Providing for public consumption positive and negative examples that illustrate the normative foundations of an institution	Disassociating moral foundations	Disassociating the practice, rule or technology from its moral foundation as appropriate within a specific cultural context
	Changing normative associations	Re-making the connections between sets of practices and the moral and cultural	Mythologizing	Preserving the normative underpinnings of an institution		

		foundations for those practices		by creating and sustaining myths regarding its history
	Constructing normative networks	Constructing of interorganisational connections through which practices become normatively sanctioned and which form the relevant peer group with respect to compliance, monitoring and evaluation	Embedding and routinizing	Actively infusing the normative foundations of an institution into the participants day to day routines and organizational practice
<i>Cognitive</i>	Mimicry	Associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption		Undermining assumptions and beliefs Decreasing the perceived risks of innovation and differentiation by undermining core assumptions and beliefs
	Theorising	The development and specification of abstract categories and the elaboration of chains of cause and effect		
	Educating	The educating of actors in skills and knowledge necessary to support the new institution		



The sustainability transitions research is built on the implicit understanding that a homogenous set of regime actors is challenged by an equally homogenous rival of a clearly defined niche actors. Niche actors are the ones who have generally been recognised to promote radically different future socio-technical system configurations (Geels, 2004; Seyfang and Haxeltine, 2012; Geels et al., 2016), while regime actors, as the more resourceful actors, will aim at watering down sustainability ambitions and push for optimising existing trajectories rather than to explore new (and more sustainable) ones (Coenen et al., 2010; Ting and Byrne, 2020). Moreover, it has been observed that due to cognitive and infrastructural lock-in, regime actors often specifically counteract ongoing change or destabilisation (Fünfschilling and Truffer, 2016). Especially when the niches grow rapidly, regime actors may start to invest in reversing policy support for niches (Hess, 2016) and to undertake defensive institutional work to maintain their dominant positions (Hensmans, 2003; Maguire and Hardy, 2009).

Niche and regime actors thus differ with regard to interests, competencies, values and worldviews and adopt corresponding strategies to promote their specific transition pathways (Coenen et al., 2010). Regime actors tend to prefer fit-and-conform strategies, while niche actors work on stretch-and-transform ones. However, the sustainability transitions literature has shown that the emergence of radical transitions cannot be attributed exclusively to peripheral niche actors (Green, 1991; Kemp et al., 2001; Geels, 2002; Garud and Karnøe, 2003; Schot and Geels, 2008; Brown et al., 2013). Rather it will be the result of interaction among actors with different degrees of incumbency (Jørgensen, 2012; Yap and Truffer, 2019). That is to say, radical institutional change requires collective actions between niche and regime actors. Thus, it begs a key question: how does the interaction process between niche and regime actors unfold, and which types of their interactions shape more or less radical institutional change?

The directionality battle between fit-and-conform and stretch-and-transform is not about whether the new (niche actors) will win over the old (regime actors). In our research we do not want to tie regime actors upfront to a strategy of maintaining institutions (defending the regime) while niche actors do the creating (building niches) and disrupting work (de-stabilising regimes). Rather, battles about the actual course of action may happen equally among regime actors within a prevailing regime as among actors supporting (potentially manifold) niches. Such a view accounts for a situation in which regime actors may operate in the niche, and have an interest building in niches, while niche actors may not want to destroy the regime and prefer to operate on the niche level only. The fact that regime actors are not just defending the status quo has also been recognized in neo-institutional literature. In the seminal work by Leblebici et al. (1991), they emphasized that internal institutional contradictions may emerge as a starting point for

dominant actors to engage with institutional change. In transition studies, Fünfschilling and Truffer (2014) elaborated how different institutional logics in a regime may create tensions within and among actors who are incumbents in the prevailing regime. We have therefore to account for a multiplicity of institutional work strategies of a multitude of actors, which are more or less tied to the prevailing regime structures.

To answer the above question about interactions between niche and regime actors, we will have to adopt a more open understanding on how different actors relate to the dominant regime. A specific actor may hold different degrees of incumbency depending on which aspect of the regime is considered (Stirling, 2019). Niche and regime actors may agree on most dimensions of the regime and just differ on very specific aspects. Smink et al. (2015a) have identified that niche and regime actors generally act under divergent institutional logics, which hinder their interactions. However, when they share institutional logics, they may establish more productive relationships (Smink et al., 2015a). Van Wijk et al. (2013) further argue that niche and regime actors may establish effective collaborations by building up learning network to facilitate their shared understanding of the sense-making and meanings.

Institutional work not only requires actors to work across niche and regime boundaries, but also across spatial boundaries. The recently proposed approach of a “geography of transitions” has started to scrutinize spatial dynamics (Coenen et al., 2012; Truffer and Coenen, 2012; Hansen and Coenen, 2015; Truffer et al., 2015). Sustainability transitions studies have traditionally focused on national level studies, assuming that niche and regime structures would be essentially uniform within a national territory (Coenen et al., 2012). As argued by Coenen et al. (2012) it is important not to conflate a conventional view on geography with levels in the Multi-Level Perspective (MLP), equating niche with local, regime with national and landscape with global processes and structures (Coenen et al., 2012; Raven et al., 2012; Bridge et al., 2013). A more geographically informed interpretation would see niche-regime interactions as happening at and across multiple scales to generate specific transition pathways (Coenen et al., 2012; Fünfschilling and Binz, 2018). The regional variation was more easily acknowledged in niche processes (Boschma et al., 2017). Raven et al. (2008) for instance stressed that geographical contextualisation was crucial for niche experiments. They argue local actors reinterpret and reinvent the generic rules, which enable local variations or the emergence of the new niche pathways. However, the regional variation of regime structures found much less resonance (for exceptions see Späth and Rohrer (2012); Binz and Truffer (2017); Fünfschilling and Binz (2018)).

To address how actors mobilize institutional work in the spatially very different contexts, we have to conceptualise the regional specificity of both niche and regime structures. Socio-technical regimes may then be conceptualised as multi-scalar structures with rules that may be interpreted by regional actors for their local contexts (resulting in regional implementation styles of national regulations). Institutional work can also be oriented towards working at different spatial levels. It can either focus on how regional actors try to shape institutions at the national level, or on how national level rules get translated selectively into specific regional contexts (see also Yap and Truffer (2019) for a similar, although not spatially delimited multi-scalar approach to directionality). Not all actors have equal capability to conduct institutional work in such a multi-scalar world. Some actors like big national companies are boundary spanners. They can more easily leverage processes across different scales, while regionally anchored small-medium sized enterprises will be more restricted. A spatial sensitive approach to institutional work is crucial to investigate how and why developments in certain regions move in divergent directions.

These multi-scalar relationships are however not limited to regions in a country. The same applies to different countries in a globally structured sector (Fünfschilling and Binz, 2018). Local actors may mobilise global networks to stabilise local niches (Sengers and Raven, 2015). For example, local actors could translate the global climate change agenda to shape local legitimacy for green technologies (Smith, 2007). It is crucial to recognise that heterogeneous local niche and regime actors may hold different interests and strategies, which enables them to mobilise different types of institutional work to shape the divergent regional visions and pathways (Essletzbichler, 2012). However, Fünfschilling and Binz (2018) remind us about the constraints provided by the global socio-technical regime, they may stifle specific type of changes at the regional and local level, despite the institutional work generated by niche or regime actors.

Based on this selective and focused literature review, we are now in the position to explore what portfolio of institutional work niche and regime actors adopt to shape divergent directions of sustainability transition. We will investigate in the case of solar PV niche development in two Chinese provinces. One case represents a rather ideal type fit-and-conform and the other a stretch-and-transform pattern. To avoid confusion we are not using the notion of transition pathway as used in the literature cited above since we are only interested in making a distinction between two patterns with a particular directionality (or direction): this is the end-shape of the reconfigured system. We will explore whether we can explain the different patterns by looking at the portfolio of institutional work assuming that such a portfolio may be responsible for the divergent patterns. We will investigate the relationships between niche and regime actors and

whether and how they work together in performing institutional work. And finally, we will reconstruct how niche and regime actors adopt their institutional work linked with the specific local context conditions and national developments.

## 5.3 Methodology

### 5.3.1 Case study selection strategy

This study adopts a comparative case study research design (Creswell, 2007; Yin, 2014). To investigate how niche and regime actors adopt institutional work to shape directionality of transition, we select two contrasting cases: solar PV development in two Chinese provinces, Inner Mongolia and Jiangsu, which represent two divergent development patterns, fit-and-conform and stretch-and-transform. Each province is considered a (sub-) case and analysed as such independently, followed by comparison across both (sub-) cases. To develop a geographic sensitive understanding of institutional work, we also elaborate state-provincial dynamics to investigate relevant institutional work across multiple scales.

The country of China is selected because of its rapid and large scale diffusion of solar PV deployment over the last decade and also its divergent regional development, which fits the purpose of this research. China holds the global largest solar PV market (see Figure 5.1). The prevailing Chinese electricity regime has been dominated by the model of centralised, large-scale power plants, long distance transmission grids operated by large utility companies over the past decades (Yuan et al., 2012). In recent years, solar PV development showed two different patterns, either promoting solar PV electricity in a form that easily connects to the centralised transmission grid or a form of energy that is produced near the place of consumption and therefore more energy efficient. Inner Mongolia and Jiangsu have been leaders in China in promoting one of these alternatives each. In 2018, the total installed capacity of solar PV in the two provinces contributed 13% of the country's total capacity. The deployment of solar PV in Inner Mongolia is mainly dominated by large-scale centralised solar power plants with long-distance transmission, while Jiangsu is leading in terms of distributed solar PV (see Figure 5.2).

The two proposed provinces represent contrasting cases exemplifying different directionalities. The development of solar PV in Inner Mongolia can be characterized as a fit-and-conform pattern, while the case of Jiangsu leans more towards a stretch-and-transform pattern. To elaborate how different actors pushed for institutional change, we focus on the period between 2000 and 2018, which covers the major diverging development phases of solar PV in China (see Figure 5.3).

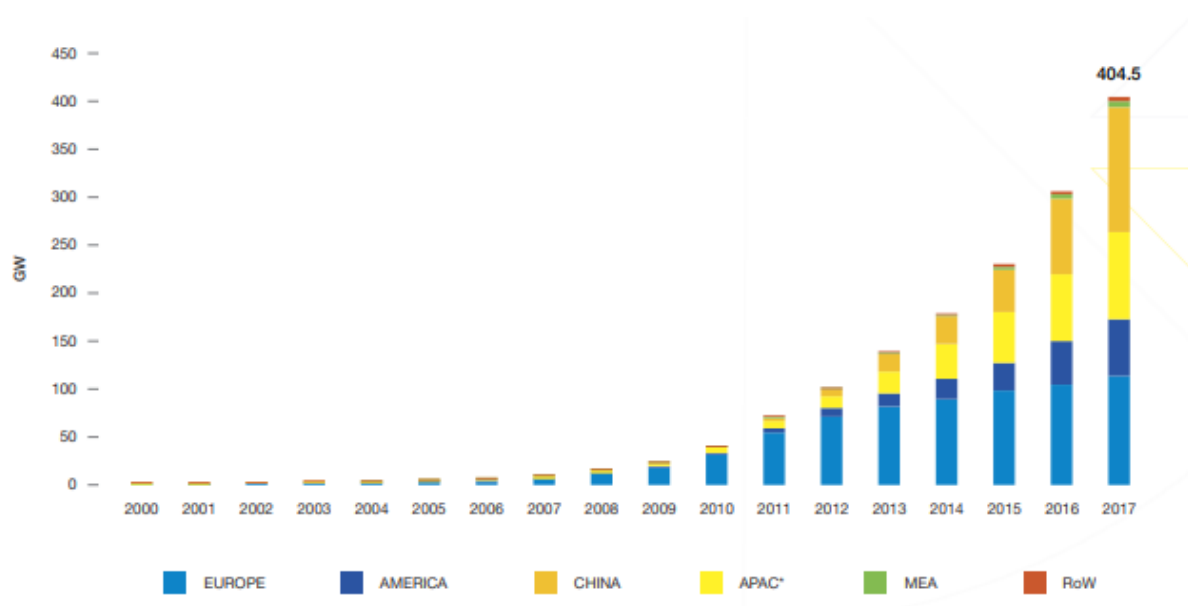


Figure 5.1. Evolution of global total solar PV installed capacity 2000-2017.  
Source: SolarPower Europe (2018)

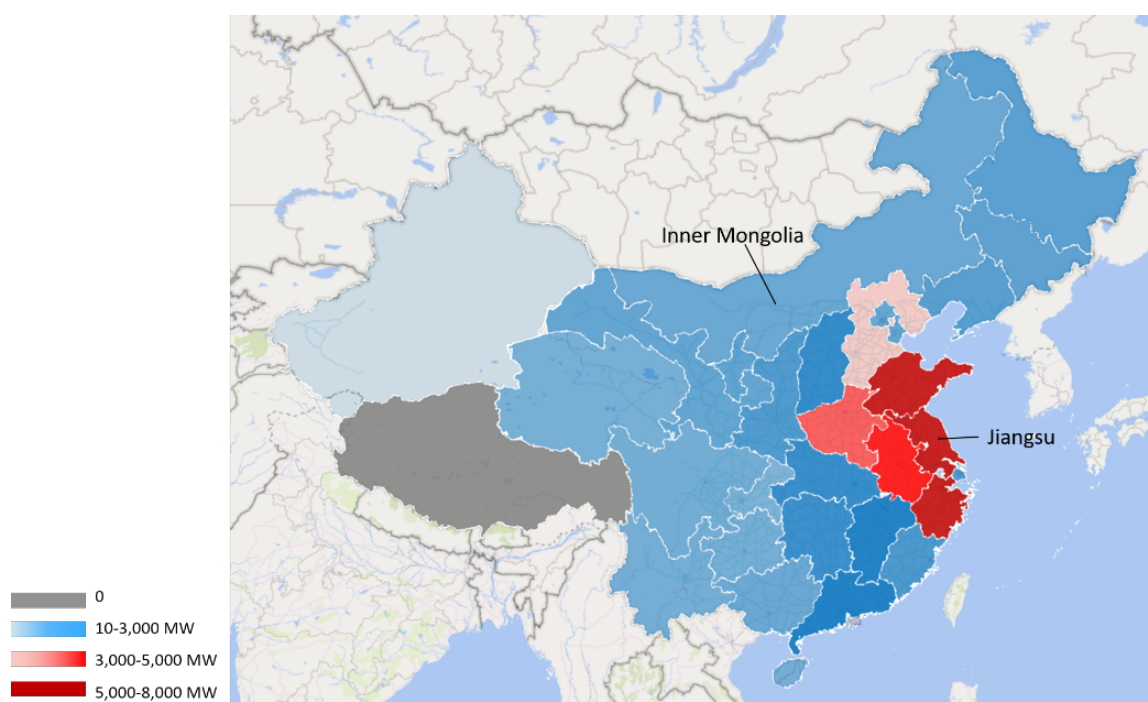


Figure 5.2. Installed capacity of distributed solar PV in China- by the end of 2018  
Source: authors' own, based on statistical data from National Energy Administration

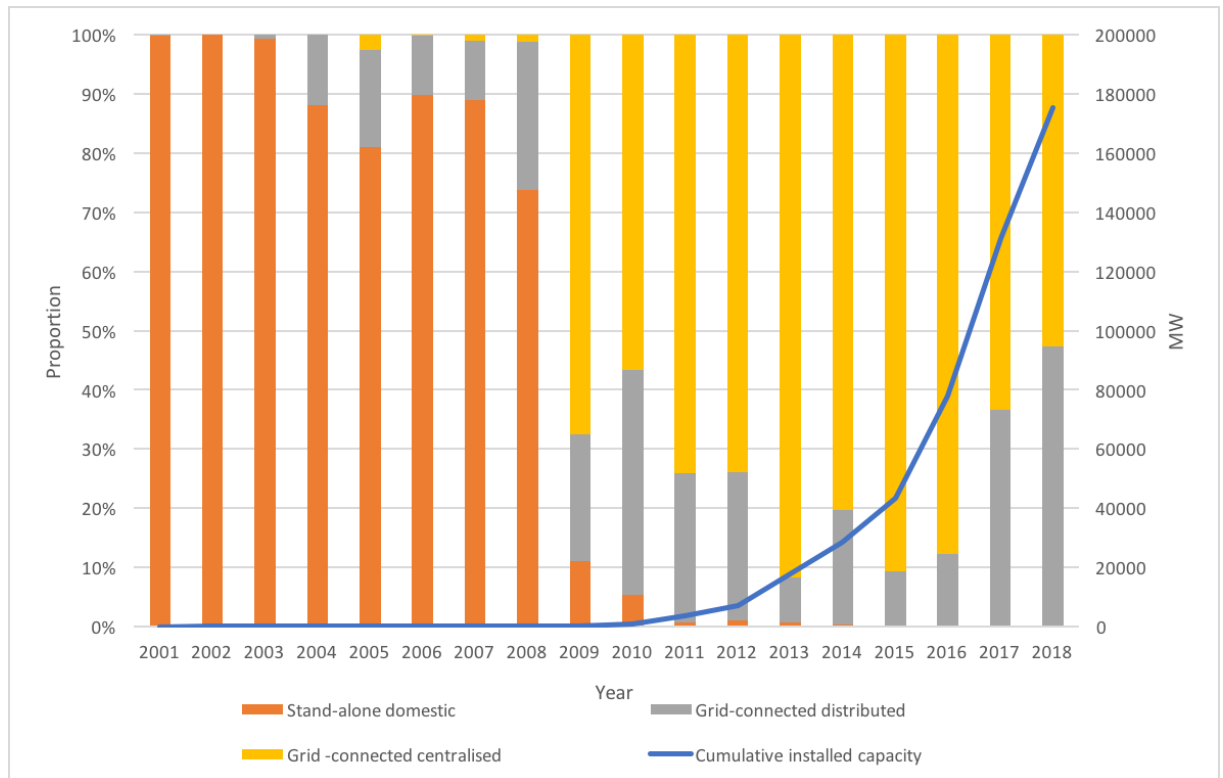


Figure 5.3. Cumulative installed solar PV power and various application market in China from 2001 to 2018

Source: authors' own, based on statistical data from Lv et al. (2018);

Note: the proportion of the various application is based on the proportion of annual new installed market, instead of the cumulative capacity;

### 5. 3. 2 Data collection and analysis

To address our research question, we need data about the institutional work of key actors involved in solar PV development in two provinces and at the national level. The study adopts a complex mix of data collection and analysis methods.

Both primary and secondary data were collected and analysed to conduct a longitudinal analysis. Primary data collection included semi-structured interviews, focus groups and workshop from two rounds of fieldwork, conducted from July 2017 to March 2018, and between December 2018 to January 2019. In total forty-two experts were approached covering a wide range of stakeholders (see Appendix Table A.1 in for the list of all the interviewees). Each interview lasted around one hour. All interviews were conducted in Mandarin, recorded with audiotape, transcribed and translated into English. The secondary data covered newspaper articles, policy documents, organisational reports, academic articles etc. Relevant industry conferences were also attended to identify key stakeholders and to collect useful documents (for example, presentation slides and conference proceedings).

During a first round of fieldwork, twenty-six semi-structured interviews were conducted. They served to identify key processes of institutional change, and the role of different stakeholders for solar PV development at the national and provincial level. To be specific, we first operationalised the three institutional pillars as depicted in Table 5.2 so that we could identify the relevant instances of institutional work. Historical changes in national and provincial regulations were identified through secondary data, such as policy documents, newspaper articles, and organisational reports. These documents were complemented and triangulated with individual interview data and workshop insights. Changes in cognitive and normative institutions were derived from the interview data.

Based on the information collected we constructed a timeline of key institutional changes at the national and provincial level at the end of first round of fieldwork. Then we invited stakeholders to a workshop in March 2018, in order to reflect on the detailed storylines (working with representatives of two provinces separately; hence we did two focus groups). The workshop served as a triangulation for the interview data and also served as an opportunity to specify the role of different stakeholders for solar PV development. In the workshop, the proactive role of local actors became obvious for explaining the diverging development patterns in the two provinces. Phrased by several participants, “the divergent development of solar power in the two provinces is largely promoted by the local actors” (workshop, 8 March 2018, Beijing).

To identify how niche and regime actors adopted different forms of institutional work, we conducted a second round of fieldwork. We ran semi-structured interviews to investigate the specific role of local actors and asked which types of institutional work they mobilized to shape the divergent transition directions. Interview has the advantage to explore the invisible and often mundane dimensions of institutional work (Fünfschilling and Truffer, 2016). In total, nineteen experts from two provinces were approached with three follow up interviews and four focus groups were conducted.

After finishing the interviews, we drew on the theoretical concepts of ‘institutional work’ as identified in Table 5.1 in order to code the interview data. The interview data was complemented and validated with secondary data, such as policy documents, news and organisational reports so that to identify how the institutional changes have been stimulated-through which types of actors, and through which types of activities. These results are presented as storylines in section 4. To highlight the types of institutional work, we numbered creating institutional work as C1-C9, maintaining institutional work as M1-M6, disrupting institutional work as D1-D3 (see Appendix Table C.2 for coding structures). Appendix Table C.3 presents further evidence of different institutional work adopted by actors at national level and in two

provinces. Moreover, we summarised these evidence in three figures (depicted in Figures 5.4, 5.5 and 5.6).

Table 5.2. Operationalisation of three institutional pillars

<b>Institutional pillar</b>	<b>Definition</b>	<b>Operationalisation</b>
Regulative	Refer to the formal rules, such as laws, government policies	Develop and implement the laws, policies or regulations either to support or disrupt regime or contribute to niches development. Such as regulations or targets oriented development plans; mandatory quota; subsidy;
Normative	Refer to the values, social norms	Values and social norms, which are mobilized to assess the superiority of either centralised or decentralised forms of power. For example, what is the priority for future energy development? Whether the priority is for economic efficiency or energy efficiency and environmentally friendly?
Cognitive	Refer to the beliefs and symbolic meanings	What are the local problems; What are actors' perceptions of energy system/ what is the meaning of energy? For example, whether energy as products or energy as the service?

## 5. 4 Solar PV development

In this section, we present the historical account of institutional change and different types of institutional work employed by both niche and regime actors for solar PV development from 2000 to 2018 in two focal provinces. To present the national conditions for the two divergent directions, we also briefly introduce the types of institutional work at the national level.

### 5. 4. 1 National level

Solar PV experienced a rapid deployment in China over the last decade (Yang et al., 2020). There was visibly no installed capacity in the country before 2000, while in the year of 2018, its cumulative installed capacity attributes to one third of the global total installed capacity in solar PV (APRICUM, 2019). The deployment of solar PV from 2000 to 2018 can be categorised into three different stages according to different dominant applications (see Figure 5.3): before 2009, off-grid stand alone energy system; since 2009, grid connected large-scale centralised power system; and since 2017, the recently boom of grid connected distributed solar PV energy system. As depicted in Figure 5.4, this process was shaped by different types of institutional work enacted by both niche and regime actors. The key regime actors involved at the national level



include the thermal power generators, grid company, central government, provincial government, and large users. The key niche actors include the solar PV manufacturing industry, solar PV generators, solar PV industry associations.

Before 2009, China's solar PV deployment was dominated by off-grid stand-alone energy systems. The majority of cumulative PV capacity was located in rural areas that were lacking access to electricity (Wallace and Wang, 2006; Li et al., 2007b; Bhattacharyya and Ohiare, 2012). Developments were mostly supported by the central government's rural electrification programmes, such as the "Brightness programme (光明工程)", "National Township Electrification Programme (送电到乡)" (National Development and Reform Commission, 2002). In 2005, China issued the Renewable Energy Law, which set the legal framework for the renewable energy deployment in China (Zhang and He, 2013). In 2007, the central government implemented the "Medium-Long term Renewable Energy development plan", which mandates the grid company to purchase all of the generated renewable energy, and the large thermal power generators to install a certain proportion of non-hydro renewable energy (3% by 2010, 8% by 2020). This policy defined a new relationship between conventional utilities and renewable energy generators [vesting, C3]. After 2006, the solar PV manufacturing industry took up rapidly in China mainly aiming at serving rapidly growing markets in Europe and the US (Fischer, 2012). The domestic application of solar PV was only marginal. In the year of 2008 for instance, only 1.5% of the country's solar PV cell production ended up serving the domestic market (China Renewable Energy Engineering Institute, 2012). The solar PV manufacturing association articulated that the over reliance on overseas markets represented a high risk for Chinese manufacturers. They therefore lobbied the central government to nurture the domestic market (interview, senior policy researcher, 14 Dec 2017, Beijing) [advocacy, C1]. Especially after the global financial crisis in 2008, when the European solar PV market shrunk massively and imports from China were banned, advocacy for supporting solar PV industry development through indigenous markets became stronger (Huang et al., 2016). In 2009, the central government initiated the "Golden Sun" project and the "Building Integrated PV" project to boost the domestic market for solar PV (Huang et al., 2016).

Since 2009, China encounters a rapid take-up of large-scale centralised solar power plants (Zhang et al., 2014). This was shaped by national solar PV manufacturing industry, together with local governments in the western part of China. They engaged in creating institutional work to address the regulative and normative pillars. To be specific, the types of institutional work that they adopted included: advocacy [C1], vesting [C3], constructed identities [C4], changed normative associations [C5] and constructed normative networks [C6]. The national solar PV

industry association constructed that large-scale solar power plants could efficiently prevent desertification of the western provinces of China [C5]. They together with provincial governments lobbied the central government to support centralised power system, arguing that the build-up of large-scale centralised solar PV power plants is an efficient way to support industry development [C1]. In 2010, the National Development and Reform Commission implemented concession projects to support 280MW large scale centralised power plants in western provinces (Inner Mongolia as one of them). At the same year, the central government denoted solar PV industry as a strategic emerging industry for a low-carbon economy. This set signals for social investors and also for local governments to support the industry [C4]. In the same year, the Chinese solar PV Industry Alliance was established, which reinforced solar PV industry's lobby power to influence national support policy (Huang et al., 2016) [C6]. From 2011, the central government set up national level feed-in tariffs for solar PV generated power [C3]. This further burgeoned the rapid deployment of large-scale power plants.

Since 2017, China witnessed a rapid increase of distributed solar PV (DSPV). This has been a result of both creating and disrupting institutional work entertained by both niche and regime actors especially in provincial level (Zhang, 2016a). This will be elaborated in section 4.3. The central government and niche actors, for example, disconnected market rewards for thermal power plants [D1], dissociated coal power from its moral foundation as the basic power for electricity [D2]. Coal power operators got challenged by the emerging requirement for moving towards a cleaner, greener and low-carbon energy sector. In 2016, the central government implemented the "Energy Supply and Consumption Revolution Strategy" policy, which capped coal power capacity by 2020 [D1]. "Clean and low carbon" have been articulated as the new vision for next generation energy system. In 2017, the National Energy Administration made a clear statement that "with the further transformation of the country's energy system, the future for coal power is to provide dispatching auxiliary service for renewable energy and to make space for renewable energy generation, while previously the function of thermal power was phrased as 'to guarantee the supply of electricity'" (Cableabc.com, 2018) [D2]. Therefore, the strategic position of coal power was fundamentally redefined. Moreover, in 2015, the central government issued "Several Opinions on Deepening Power Sector Reform (Zhongfa [2015] No. 9 document)" policy to launch a new round of liberalisation-oriented reforms of the electricity sector. This reform aims to refine the market mechanism, such as empowering new actors for the retail market, develop inter-regional and provincial trading markets, and building spot markets (Zhang et al., 2018). It thus exerted pressures which undermined the monopoly power of the state grid.

To respond to the challenge, regime actors (thermal power generators and grid companies) also proactively shape institutional change, through valorising and demonizing [M4]. In recent years, coal power regime actors publicly rebuild the good image of thermal power plants to maintain its strategic position in the electricity system. The coal power regime actors valorised the benefits of coal power plants as guaranteeing safety and stability of the electricity system, while, demonising the grid connection of solar PV as causing stability problems. Moreover, they argued that China's coal power plants have been much cleaner in terms of waste emissions compared to the level of 2013 (Lingnengzhe, 2019). Furthermore, coal power plants can offer more jobs compared to renewable energy (Zhao et al., 2013) [M4].

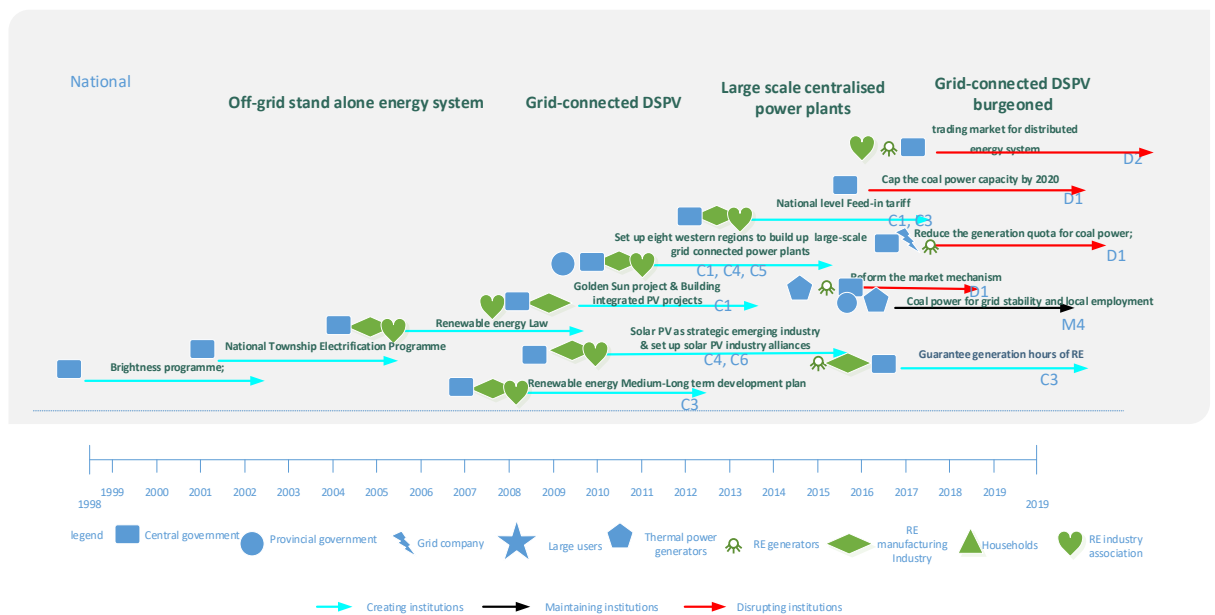


Figure 5.4. Institutional work and historical institutional change for solar PV development at national level

#### 5. 4. 2 Inner Mongolia: fit-and-conform pattern

Inner Mongolia is leading in China's renewable energy deployment. By the end of 2017, renewable energy contributed to 15.52% of the province's total electricity generation mix, of which solar, wind and hydropower contributed 2.55%, 12.45% and 0.53% respectively, while coal power contributed 84.47% (Data from the Inner Mongolia Electric Power Association). Solar PV was predominately installed in the form of large-scale centralised power plants. By the end of 2018, the total installed capacity of solar PV in Inner Mongolia was 9.45GW, of which 9.12GW (i.e. 97%) was in the form of centralised power plants [data from National Energy Administration].

The overall impact of PV on the electricity regime in Inner Mongolia can be characterized as following a fit-and-conform pattern. As depicted in Figure 5.5, the deployment of solar PV in

Inner Mongolia was shaped from early stage off-grid towards large-scale centralised power system. This has been shaped by different types of institutional work that leveraged by both niche and regime actors across different scales (both provincial and national level). The key regime actors involved in Inner Mongolia include the thermal power generators, the provincial grid companies<sup>13</sup>, the provincial government, large users (represented as different shapes in blue colour in Figure 5.5). The key niche actors include the solar PV manufacturing industry, solar PV installers and operators, and the solar PV industry association (represented as different shapes in green colour in Figure 5.5).

Solar PV was initially targeted in Inner Mongolia to serve remote areas, which lack access to electricity (Li et al., 2007b; Huo and Zhang, 2012; Zhang and He, 2013). This has been mainly supported by the central government's rural electrification programmes (dotted arrow from national level to Inner Mongolia in Figure 5.5). These demonstration programmes were predominately off-grid residential solar PV systems.

Since 2005, both national solar PV manufacturing industry and provincial government positioned Inner Mongolia as the perfect national site for large-scale solar power plants. They adopted different types of institutional work, such as lobbying [C1], vesting [C3], constructing identities [C4], changing normative associations [C5] and constructing normative networks [C6] to achieve this goal (see Figure 5.5). In 2005, Inner Mongolian experts collaborated with national level research institutes in writing a report named "Inner Mongolia Energy Development Strategy Research" (Inner Mongolia local government, 2006). They pointed out that positioning Inner Mongolia as the national energy supply sites was the solution for national energy security concerns [C4]. As further advocated, solar PV was perceived as part of this strategy. The report furthermore argued that Inner Mongolia has decisive resource advantages with good solar incidence and large areas of available land, which is suitable for the installation of large-scale centralised PV power plants. These perceived advantages were mobilised by both the national solar PV industry association and also the Inner Mongolian provincial government to lobby the central government that Inner Mongolia should be prioritised for building large-scale solar power plants (Hu et al., 2004) [C1, C4]. According to the local policy advisory experts, "if we use half of the size of the desert in Inner Mongolia to build solar PV plants, then it can substitute electricity generation of all coal power plants across the country" (Inner Mongolia local government, 2006) [C5]. Moreover, the deployment of large-scale grid connected solar power plants was regarded as one of the key strategies to promote the province's economic

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<sup>13</sup> There are two grid companies operated in Inner Mongolia, the State Grid Inner Mongolia Eastern Power and Inner Mongolia Power Group. They operated independently in the east and west part of Inner Mongolia respectively.

development and environmental benefits (China Economy Informatization, 2014). This fits the purpose of central government's political agenda to support the economic left behind provinces in the western part of China (dotted arrow from Inner Mongolia to national level). The connection of solar PV with the national political agenda leveraged political legitimacy for central government support. In 2011, the central government identified Inner Mongolia as the national energy supply site as formulated in the policy document "Promote the Inner Mongolia Autonomous Region's Economic and Social Development" (issued in 2011).

Since 2012, renewable energy encountered high curtailment issues in Inner Mongolia due to the stand-still of large scale solar and wind power plants, which caused huge economic losses (Zhao et al., 2012b; Liu et al., 2018). In 2012, the curtailment rates of renewable energy reached above 10% in Inner Mongolia. This undermines the political legitimacy for central government's support to the region as the site for instalment of large-scale renewable energy power plants. To relieve this pressure, the local regime actors argued that a strong national transmission grid was a prerequisite for rapidly increasing the clean energy share in the national electricity mix [C5]. When the value of green and low carbon was increasingly shared in society, grid companies mobilised the narrative of transmitting clean energy from Inner Mongolia to other regions to further lobby central government to support the construction of ultra-high voltage grids in order to consolidate the legitimacy of centralised power systems [C1]. The local electric power association expected that electricity demand would continuously grow in the southern part of China. Inner Mongolia could be the clean energy supplier for the country because of its rich renewable energy resource endowment [C6]. Furthermore, the large economies of scale of the massive deployment of PV panels was said to help achieving the cost target of grid parity [C5]. Aligning with national policy to relieve the above accelerated high curtailment problems of renewable energy (dotted arrow from national level to Inner Mongolia), in 2018, the provincial solar PV industry association implemented the "Actions to Reduce the Curtailment of Clean Energy in Inner Mongolia", which aims to achieve zero curtailment of renewable energy by the end of 2020 [C3]. To achieve this and following the national level electricity sector's reform (dotted arrow from national level to Inner Mongolia), the provincial government formulated new policies, such as encouraging direct trade among renewable energy generators and large users to further consolidate the market advantages of the large-scale centralised power system [C6].

At later stage, we observe regime actors proactively mobilised maintaining institutional work to defend the thermal power dominated centralised power regime (black line in Figure 5.5). The local regime actors (grid company and thermal power generators) adopted valorising and

demonizing [M4] to maintain the legitimacy of large-scale power plants. Furthermore, strategies were adopted to encourage supply side flexibility optimisation, such as flexibility retrofit of coal power plants, and set-up auxiliary service markets [M2]. However, limited attention was given to demand side flexibility.

In summary, all the above referred institutional work mainly addressed regulative and normative pillar while less addressed the cognitive pillar. This has been confirmed by one of the local interviewees, who criticised the lack of cognitive change in the province: “If you treat wind and solar power the same as thermal power plants, and use the idea of managing the big thermal power plants to manage them, then it won’t work. Using the same rules and practices as building the big thermal power plants won’t suit the further development of solar and wind power in China” (workshop participant, 7 March 2018, Beijing).

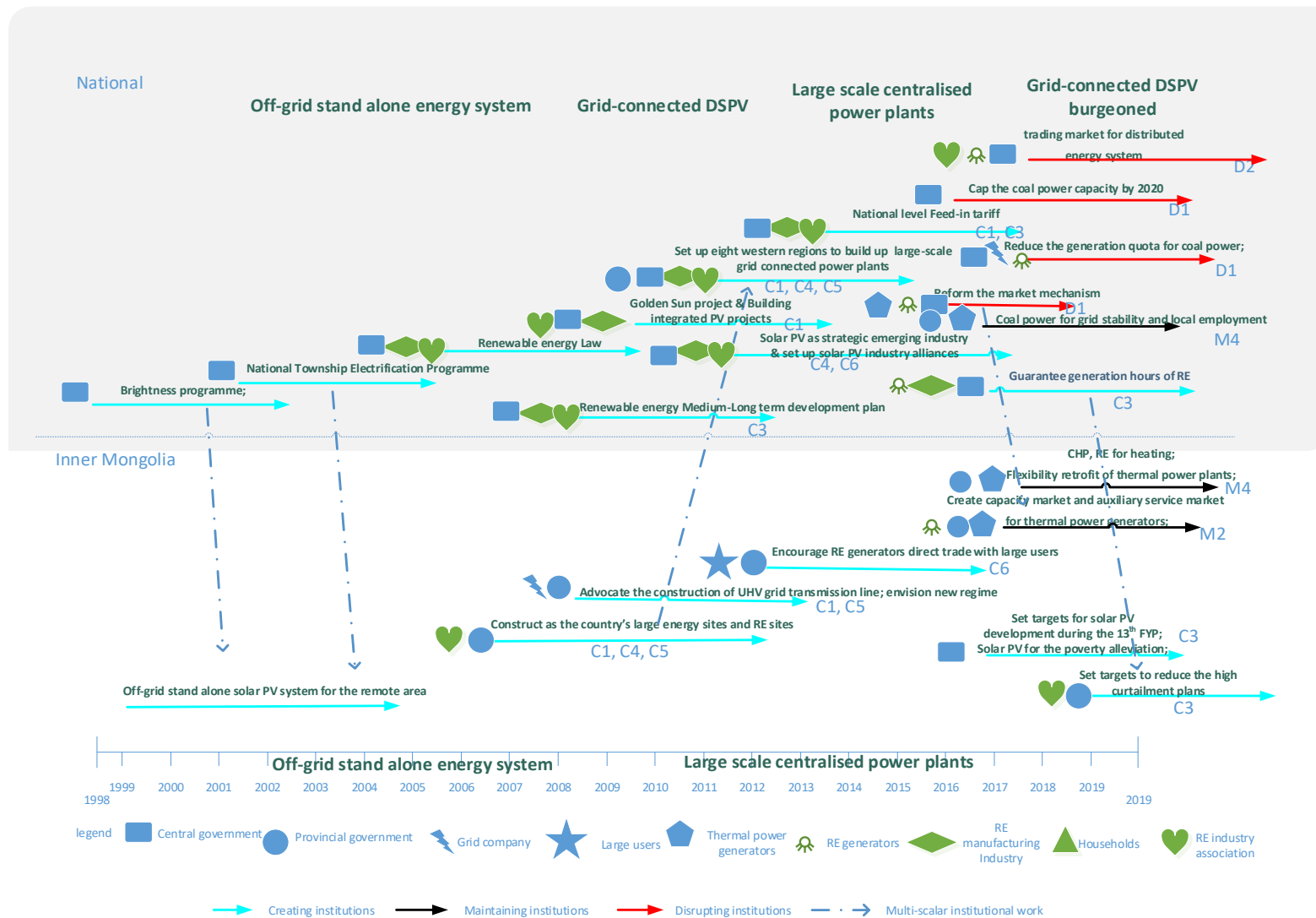


Figure 5.5. Institutional work and historical institutional change for solar PV development in Inner Mongolia and national level

#### 5. 4. 3 Jiangsu: stretch-and-transform pattern

Jiangsu province has been historically leading the country's installed capacity of DSPV. By the end of 2018, the total installed capacity of solar PV in Jiangsu province was 13.32GW, of which 40.5% is DSPV. The province is a national leader in DSPV as it represents 25.8% of the national DSPV cumulative capacity. Solar PV generation furthermore contributed 0.937%<sup>14</sup> to the province's electricity mix. Although this market share seems marginal, it has experienced rapid increase in the last decade.

Overall, DSPV has substantially "stretched and transformed" the local centralised power regime in Jiangsu. As presented in Figure 5.6, this has been shaped by different types of institutional work adopted by niche and regime actors address all three institutional pillars (cognitive, normative and regulative) across both provincial and national level. We observe actors adopted both creating (neon blue line in Figure 5.6) and disrupting (red line in Figure 5.6) institutional work. These portfolios of institutional work together fundamentally transformed the large-scale centralised power regime, which finally led to a stretch-and-transform pattern. The key regime actors involved in Jiangsu include the thermal power generators, the provincial grid company, and the provincial government (represented as different shapes in blue colour in Figure 5.6). The key niche actors include the solar PV manufacturing industry, solar PV generators, small-medium sized solar PV installers, and the solar PV industry association (represented as different shapes in green colour in Figure 5.6).

The local niche actors have been very actively shaping the institutions for the deployment of solar PV in the province. The main relevant types of institutional work include: lobby [C1], vesting [C3], constructing identities [C4], changing normative associations [C5], constructing normative networks [C6], theorising [C8] and educating [C9].

In the early 2000s, the local solar PV manufacturing enterprises, which are national leaders of this industry, proactively lobbied the local government to support solar PV deployment in the province (Li et al., 2007). Due to the then increasing electricity shortage problems in the province, solar PV was regarded as one of the solutions to supply clean electricity to the city. Local small and medium sized enterprises played a leading role to invest in PV, which made the region become the leader in the Chinese solar PV market (CIConsulting, 2010). Especially after the global economic crisis in 2008, the local solar PV manufacturing industry association proactively

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<sup>14</sup> Calculated by the author= the generation from solar PV/ the provincial's total electric power generation. Note: The size of electricity demand in Jiangsu province is twice the size of Inner Mongolia. Although the market share of solar PV generation in Jiangsu province's electricity mix is smaller than Inner Mongolia, the scale of installed capacity of solar PV in Jiangsu province is larger than Inner Mongolia.



lobbied the provincial government to implement a feed-in tariff to nurture indigenous market so that to prevent large scale bankruptcies in the Chinese industry (Grau et al., 2012; Huo and Zhang, 2012). In 2009 the provincial government followed this advice (interview, president of Jiangsu provincial solar PV industry association, 21 Dec 2017, Nanjing) and set up the country's first provincial level feed-in tariff (see the policy "Opinions to promote solar power in Jiangsu province (江苏省光伏发电推进意见(苏政办发〔2009〕85号))" [C1, C3]. This exemplary provincial level policies also set the moral foundation for the later installed national level supportive policies (dash line with arrow from provincial level to national level in Figure 5.6). The implementation of the provincial subsidy policy contributed massively to the rapid increase of installed PV capacity in Jiangsu. By the end of 2011, the province had installed 400MW of grid-connected solar PV (compared to 40 MW by the end of 2009), which contributed 20% of the country's total installed capacity in this year.

Moreover, the local solar PV investors theorised new futures of the energy system and constructed new identities and values for solar PV. Since 2014, the local solar PV investors, such as small and medium sized enterprises, and the local solar PV manufacturing industry constructed strong narratives that more localised energy should be used because it is more energy efficient [C5]. They argued that the deployment of renewable energy offers opportunities for the province to achieve a higher share of clean and green energy in the local electricity mix [C4, C5]. The deployment of distributed energy was perceived to hold a bright future in Jiangsu province. With limited available land, it has less advantage to deploy large-scale solar PV power plants. On the contrary, with its concentration of large electricity consumers, such as industrial parks, Jiangsu province is the perfect site to adopt distributed solar PV energy (China's Renewable Energy development outlook, 2017) [C8]. As a result, the provincial "13<sup>th</sup> Five-Year Plan for Energy Development (2016-2020)" portrayed DSPV as the main development pattern for Solar PV deployment in Jiangsu. This led to the local investors developed more diversified business models to promote further DSPV deployment (Zhang, 2016b) [C5]. Apart from rooftop based distributed solar PV, "solar PV +" business models emerged, such as "solar PV+ water-related affairs", "solar PV+ fishing", "solar PV+ agriculture", "solar PV+ transportation" (Statistical bureau of Jiangsu province, 2017).

Furthermore, the local solar PV investors collaborated with the municipal government to further demonstrate local experimentations to connect solar PV with broad social values. For example, in 2015, Yangzhong, one of the cities in Jiangsu province, set the goal to build 'China's Green Energy Island' (Sun, 2017), and set-up a special funding scheme to promote public building integrated and household rooftop based distributed solar PV. It demanded that by 2030,

renewable energy should contribute 100% to the local energy consumption [C3, C5]. Another city, Zhenjiang also supported grid-connected building integrated solar PV systems considering it as the crucial strategy for low-carbon city development (Wang et al., 2015). In January 2014, the village located in Donghai County of Lianyungang municipality was the first demonstration programme with rooftop distributed solar PV systems connected to the grid in Jiangsu province. This local experimentation demonstrated the deployment of household solar PV energy systems as being a success case to contribute to an ecological lifestyle. It evaluated this programme to have saved 128 tons of coal and to cut down CO<sub>2</sub> emissions by 341 ton per year. The village soon became a national model for “ecological civilisation” and “beauty China” (Xinhua News Agency, 2014, 2018) [C5, C8].

Local solar PV installers also educated users to further promote the local diffusion of DSPV. For example, Wuxi municipal government worked together with the local solar PV installers to promote “solar PV enter households (光伏进万家-无锡)” activity. These educating activities enabled users to understand better about DSPV [C9]. These local solar PV installers also build heterogenous alignment network with local government and local grid company to explore the institutional support for DSPV deployment. These local networks enabled the local grid company to construct new identities for a next generation of power grids [C4, C5]. New values, flexibility and smartness, have been formulated. With the fast penetration of rapid increase of electric vehicles in the province, the local grid company confronted great challenges. The grid company believed that distributed energy systems could contribute to the resilience of the grid. This motivated them to construct a new identity in the future electricity system [C4]. As phrased by an interviewee from the grid company in Jiangsu:

The utilities need to change the perception of their identities in the electricity market from being CHP (cooling, heating and power) providers to becoming energy service providers. This requires the grid company to provide more efficient energy services in order to respond to the diversified user demand. The age of the traditional one direction business model, from the grid company to the users, electricity transmission model will become the past. (project manager, 8 January 2019, Nanjing).

In 2014, the grid company implemented the national first guidance for solar PV grid connection. This has been a big contrast to the situation in some other provinces where the grid company forbade self-generated solar PV power because they worried that it enables power to be sold to third parties or other consumers which could undermine their benefits. In Jiangsu, heterogenous actors between the local installers, local grid company and the local government have built wide networks for local experimentations which are a result of lobby from the local solar PV enterprises (interview, president of Jiangsu provincial solar PV industry association, 9 January 2019, Nanjing) [C1].

Moreover, we also observe niche actors enacting more visible disruptive institutional work at later stage in Jiangsu, which include disconnecting sanctions [D1], disassociating moral foundations [D2] and undermining assumptions and beliefs [D3]. Jiangsu province has been one of the leading provinces to implement the provincial policy to cap the provincial level coal power plants by 2020 (“263 action plan”, 2016) [D1]. Articulated by the local industry association, with rapidly decreasing panel cost, solar PV became more and more economically competitive. It could finally challenge the thermal power in the market [D2]. The narratives that distributed power generation near place of consumption could be more economic and energy efficient. This undermined the assumptions and beliefs about large-scale power plants and long-distance transmission line being more economically efficient or leading to more stable electricity provision [D3]. Under the background of national electricity sector’s reform (issued in 2015), the province adopted strategies such as peer to peer trading to encourage the deployment of DSPV (see the provincial policy “Market trade Guidance for DSPV generation (分布式发电市场化交易规则)”, 2019) (dash line with arrow from national level to provincial level). This allows the prosumers sell electricity independently to any consumers with a signed contract. It undermined the monopoly power of big utilities in the electricity retail market, which enables to further transform the thermal power dominated centralised power regime.

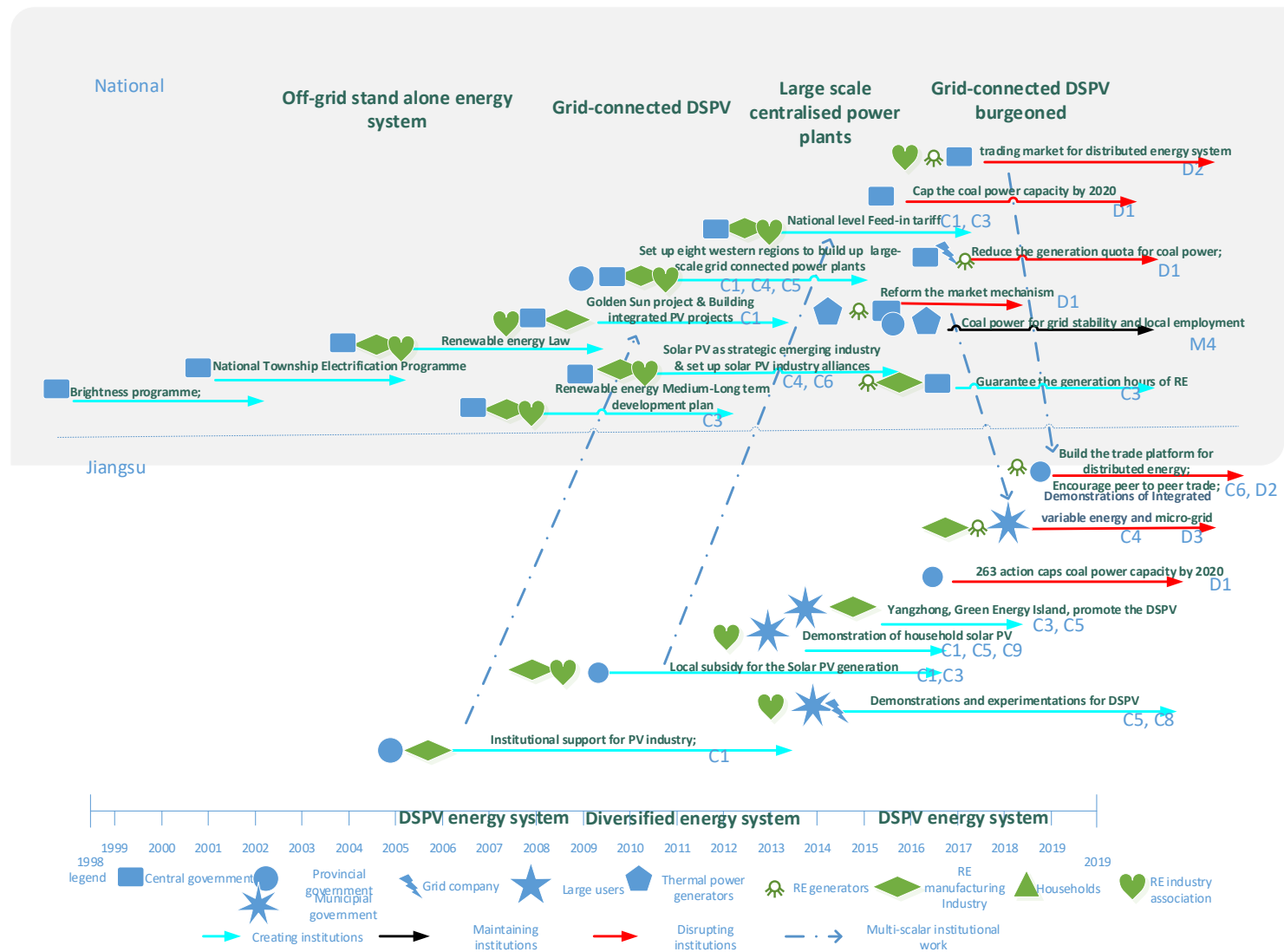


Figure 5.6. Institutional work and historical institutional change for solar PV development in Jiangsu and national level

## 5. 5 Discussion

In this section, we will discuss how niche and regime actors adopted different forms of institutional work by elaborating on three aspects: i) the portfolio of institutional work enacted; ii) the interactions between niche and regime actors; iii) the multi-scalar dimension of institutional work.

### 5. 5. 1 Portfolio of institutional work

Both our cases show that actors engaged in a rich array of institutional work identified in the literature. In other words, the institutional work portfolio differed substantially between the two provinces. In section 2, we categorised institutional work along two axes: institutional pillars (regulative, normative, cognitive ones) and types of institutional work (creating, maintaining and disrupting). In our case analyses presented in section 4, we mapped the portfolio for both provinces (see Figures 5.5 and 5.6). This enables us to compare the portfolios of institutional work across cases. Table 5.3 summarises the various forms of institutional work presented different pillars by colour code.

Table 5.3. Divergent portfolio of institutional work in two provinces

	Forms of institutional work	Inner Mongolia	Jiangsu
Creating institutions	Advocacy	√	√
	Vesting	√	√
	Constructing identities	√	√
	Changing normative associations	√	√
	Constructing normative networks	√	√
	Theorising		√
	Educating		√
Maintaining institutions	Enabling	√	
	Policing	√	
	Valorising and demonizing	√	
Disrupting institutions	Disconnecting sanctions		√
	Disassociating moral foundations		√
	Undermining assumptions and beliefs		√

Legend: √ indicates that we observe actors adopt the corresponding form of institutional work.

Light background blue colour corresponds to the regulative pillar;

Light background orange colour corresponds to the normative pillar;

Light background pink colour corresponds to the cognitive pillar.

The Jiangsu case shows that the stretch-and-transform pattern corresponded to actors adopting a portfolio of creating and disrupting institutional work (ignoring maintaining work), while

addressing all three institutional pillars. We characterise the portfolio using the three pillars as an entry point. The Jiangsu actors shaped the **cognitive** pillar through theorising and educating (along the creating institutions axis) and through undermining assumptions and beliefs (along the disrupting institutions axis) (see Table 5.3). Niche actors educated users and theorised by voicing expectations on how future solar PV system would fit in a radically transformed electricity system based on more localised and energy efficient distributed generation. This undermined core assumptions and beliefs of the regime, namely that the primary task of the sector is to rely on cost-efficient large-scale centralised power plants, and hence long distance transmission lines. Second, the niche actors were also providing moral and cultural foundations for the de-centralised system (work belonging to the creation of institutions focusing on the **normative** pillar) and disassociated the moral foundations of thermal power plants (disrupting institutions with a strong normative pillar). The local solar PV industry -- especially the small medium sized enterprises -- actively constructed and mobilised normative and positive associations between solar PV and a local low carbon and green energy system while thermal power was criticised as unsustainable. Other work belonging to the normative pillar consisted of mobilizing support for new business models that defined new identities to regime actors as energy service suppliers and build networks for new institutional support for distributed solar PV energy system. For instance, peer-to-peer trading schemes allowed prosumers sell surplus electricity to other users and therefore encroached on the established business model of the centralised grid company. Finally, we observe that local actors (local government, solar PV generators) also engaged in a mixture of creating and disrupting institutional work to reshape the **regulative pillar**. Local solar PV associations lobbied the provincial government for subsidies and other support resulting in vesting of targets and subsidies by the province (along creating institutions axis). The provincial government also disconnected sanctions for coal power plants, which includes capping coal power plans and reducing their subsidies (along disrupting institutions axis).

The Inner Mongolia case shows that a fit-and-conform transition pattern is more likely when actors adopt a portfolio of creating and maintaining institutional work and privilege the regulative and normative institutional pillar.

Inner Mongolia actors shaped the **normative** pillar through changing normative associations, constructing normative associations and networks (along the creating institutions axis) and valorised the centralised power plants and demonizing decentralised power plants (along the maintaining institutional work axis). Inner Mongolia niche actors constructed normative associations of solar PV to the green and low-carbon values. As green and low-carbon visions

became widely shared in society, the local regime actors actively adapted their grid development strategy to accommodate for an increasing share of renewable energy in the electricity mix. However, the Inner Mongolian grid company argued that the integration of solar power in the local grid would undermine the stability to further integrate solar energy to the large-scale centralised system. Moreover, the local regime actors adopted advocacy, vesting (along creating institutional work), enabling and policing (along maintaining institutional work) to address the **regulative** pillar. More specifically, the regional Grid company strongly argued in favour of building more long-distance transmission lines in order to transmit clean energy from Inner Mongolia to other Chinese regions. Also, the local government encouraged the direct trade between large scale renewable energy generators and large-scale electricity users. This established new market relationships further consolidated the large-scale centralised power system. These forms of institutional work forcefully ‘fit’ the development patterns of solar PV in order to ‘conform’ to the centralised system logics. Compared to Jiangsu, there has been less institutional work related to the cognitive pillar. Although Inner Mongolia articulated the strategic role of renewable energy for a future green, low-carbon energy system, the local actors were less eager to confront some fundamental problems of the existing centralised energy system. For instance, to address the high curtailment problems of the centralised renewable energy plants in the region, the local solar PV industry association formulated target oriented regulative measures to encourage more integration of solar PV in the centralised power grid, instead of criticising the lacking flexibility of the existing electricity system.

Two differences between two cases stand out. We have formulated them in terms of propositions about generalised relationships that we would expect to find also in other cases:

**P1:** The directionality of a transition will more likely follow a stretch-and-transform pattern if niche and regime actors adopt a portfolio of institutional work that consists of both creating and disrupting institutional work (while ignoring maintaining institutional work) and address all three institutional pillars.

**P2:** The directionality of a transition will more likely follow a fit-and-conform pattern if actors focus on creating and maintaining institutional work (while neglecting disrupting institutional work) and address both regulative and normative institutional pillars.

In both propositions we do not make a distinction between niche and regime actors, in fact in section 4 we have shown they both engage in various types of institutional work. This begs the questions about their identities and relationships.

### 5. 5. 2 Niche-regime interactions

Remarkably both our cases show that niche and regime actors can adopt very diverse types of institutional work: creating, maintaining, disrupting (see Figures 5.5 and 5.6). For example, in the case of Inner Mongolia, we saw that regime actors (the local government and the local grid company) engaged in creating institutional work, contributing to the development of solar PV, while they also developed maintaining institutional work to further consolidate the legitimacy of centralised power plants. This contrasts with the conventional understanding in transition studies where niche actors are mostly supposed to focus on niche creation and regime actors prefer to maintain the prevailing rule systems. The conventional view sees the fit-and-conform and stretch-and-transform as essentially unidirectional processes, which suppose niche actors to either ‘fit’ to or ‘stretch’ the regime. We conclude from our study that the directionality should better be understood as a bidirectional process shaped by both niche and regime actors (this resonates by recent studies (Mylan, Morris et al., 2019)).

However, in our cases there is still a difference in terms of outcome. In Inner Mongolia regime actors were leading the institutional work that led to a fit-and-conform pattern, while in Jiangsu the institutional work was dominated by niche actors and resulted in a stretch-and-transform pattern. This dominance of either regime or niche actor is rather obvious in our cases. In general, we argue however that we have to look beyond the dominance of either niche or regime actors. Instead we should focus on niche-regime interactions.

In the case of Jiangsu province, we observe substantial local experimentations developed in networks of niche and regime actors. Niche actors are large solar panel manufacturers, and a large numbers of local solar PV installers. These local small and medium sized enterprises held close interactions with the local municipal government, which enabled them to gain local government support for experimenting with distributed solar PV. Moreover, the provincial industry association was able to communicate with the provincial government about the needs of the PV industry, which led to the adaptation of local institutions to the needs of solar PV. In Inner Mongolia, the niche-regime interaction was happening as well, but was not leading to any positive synergies in terms of institutional work. Some local niche actors (local solar PV generators) initiated disruptive institutional work. But they were unable to collaborate with regime actors who perceived limited promise to engage proactively in decentralised PV. This lack of niche-regime interactions shaped the movement towards a fit-and-conform pattern. In more general terms, we propose the following proposition:

**P3:** Stretch-and-transform patterns are more likely if niche actors play a leading role in shaping institutional change working with regime actors, while fit-and-conform patterns are more likely



when regime actors play a leading role, and are in the position to ignore the disruptive institutional work of niche actors.

### 5. 5. 3 The multi-scalar dimension of institutional work

As a third aspect of conceptual refinement of the institutional work perspective, we identified the need to look at the multi-scalar dimensions. In our case, this relates mostly to the way actors selectively interpret or intentionally shape institutions at national level in order to support the respective transition directions at the provincial level. Two key insights can be generated from our analysis.

First, local actors proactively leveraged opportunities that resulted from the different niche and regime structures in the two regions (see dotted arrow from national level to provincial level in Figures 5.5 and 5.6). We observe that local actors selectively mobilised national context conditions (policies, visions, infrastructures) to achieve their preferred regional transition directions. For example, Jiangsu intentionally emphasized the liberalisation-oriented electricity reform in order to open windows of opportunity for small medium sized enterprises, while Inner Mongolia mobilised the national development strategy for the western provinces to position itself as the leading clean energy supplier in China. This created the legitimacy for Inner Mongolia to build up the ultra-high voltage infrastructure for more centralised large-scale power plants.

Moreover, the two provinces interpreted national policies differently in order to encourage experimentation with different forms of solar PV integration into the grid. In the new round electricity sector's reform (No.9 document), different provinces adopted divergent local experimentations. Jiangsu actors chose more disruptive market mechanisms, for example, encouraging peer-to-peer trading mechanisms, to support the deployment of distributed solar PV. Inner Mongolia mainly aimed for market mechanisms to maintain the centralised power system, such as those required for cross-regional trade, which imply long distance transmission of electricity. Moreover, it encouraged direct trade of renewable energy with large users, and build-up auxiliary service markets for thermal power plants to further protect the market advantages of large-scale power plants (Liu and Tan, 2016).

Secondly, provincial actors not only proactively mobilised external resources to fulfil the local energy vision, they also enacted different forms of institutional work to shape conditions at the national level, in order to support their preferred transition directions (see dotted arrow from provincial level to national level in Figures 5.5 and 5.6). For example, Inner Mongolian actors directly lobbied the central government to position the region as the country's predominant

energy producer. The close network between the central and the local government of the western part of China enabled the mobilisation of national resources to achieve the regional targets. This is in line with similar strategies observed for the case of wind power (Hu, 2014).

Moreover, large manufacturing enterprises shaped institutional change across different scales. For example, the large solar panel manufacturers in Jiangsu province, such as Trina Solar, Xiexin, Suntech, have been actively shaping both the provincial but also the national level policies. In 2010, these big players together with other partners built up the Chinese solar PV Industry Alliance, which reinforced their power to lobby for national solar PV supportive policy, such as domestic feed-in tariffs (Huang et al., 2016). The strong capability of these local actors in Jiangsu province enables the region to adopt a preference for distributed solar PV energy system even before the central government opens up to this priority before 2013.

The importance of multi-scalar institutional work in these two provinces challenges the conventional understanding of China's renewable energy development as a process steered by central government. Most existing studies portray China's rapid renewable energy deployment as resulting from central authorities' active intervention to nurture domestic market and domestic industry (Lewis, 2013; Harrison and Kostka, 2014; Mathews, 2014; Hochstetler and Kostka, 2015; Chen and Lees, 2016; Korsnes, 2019). However, our two cases indicate that the two provinces' divergent transition patterns are the outcome of interactive process between niche and regime actors across multiple scales (provincial and national level) to intentionally shape socio-technical development. We translate this finding into our final general proposition:

**P4:** Institutional work has a multi-scalar dimension that should be taken into consideration, it will influence the directionality of the transition in terms of emergence of a fit-and-conform or stretch-and-transform pattern.

#### 5. 5. 4 Towards a potential conceptual framework: co-evolve process among three key aspects

The above research findings suggest the three aspects we have selected to focus on in our research on the role of institutional work in shaping the directionality of transitions all matters. We have summarized this finding in 4 propositions (see Table 5.4).

Table 5.4. Propositions on how portfolios of institutional work adopted by niche and regime actors across spatial boundaries shapes the directions of sustainability transitions in terms of fit-and-conform and stretch-and-transform pattern.

Three aspects	Propositions
Portfolio of institutional work	<b>P1:</b> The directionality of a transition pattern will more likely follow a stretch-and-transform pattern if niche and regime actors adopt a portfolio of institutional work that consists of both creating and disrupting institutional

	<p>work (while ignoring maintaining institutional work) and address all three institutional pillars.</p> <p><b>P2:</b> The directionality of a transition pattern will more likely follow a fit-and-conform pattern if actors focus on creating and maintaining institutional work (while neglecting disrupting institutional work) and address both regulative and normative institutional pillars.</p>
Niche and regime interactions	<p><b>P3:</b> Stretch-and-transform patterns are more likely if niche actors play a leading role in shaping institutional change working with regime actors, while fit-and-conform patterns are more likely when regime actors play a leading role, and are in the position to ignore the disruptive institutional work of niche actors.</p>
Multi-scalar of institutional work	<p><b>P4:</b> Institutional work has a multi-scalar dimension that should be taken into consideration, it will influence the directionality of the transition in terms of emergence of a fit-and-conform or stretch-and-transform pattern.</p>

We suggest that these propositions covering three key aspects can be seen as a new conceptual framework to be used in other studies when to understand how actors adopt institutional work to shape divergent directions of sustainability transitions. The portfolios of institutional work adopted by niche and regime actors matters, taking into account how they cross both spatial and niche and regime boundaries. The relationship between these aspects co-evolve during the process. In other words, it can be formulated as follows (see Figure 5.7): the directionality of a sustainability transition in terms of fit-and-conform and stretch-and-transform need a portfolio of institutional work executed by both niche and regime actors, who mobilise not only regional and local contexts but also national developments. We can add global ones, although they were not studied by us.

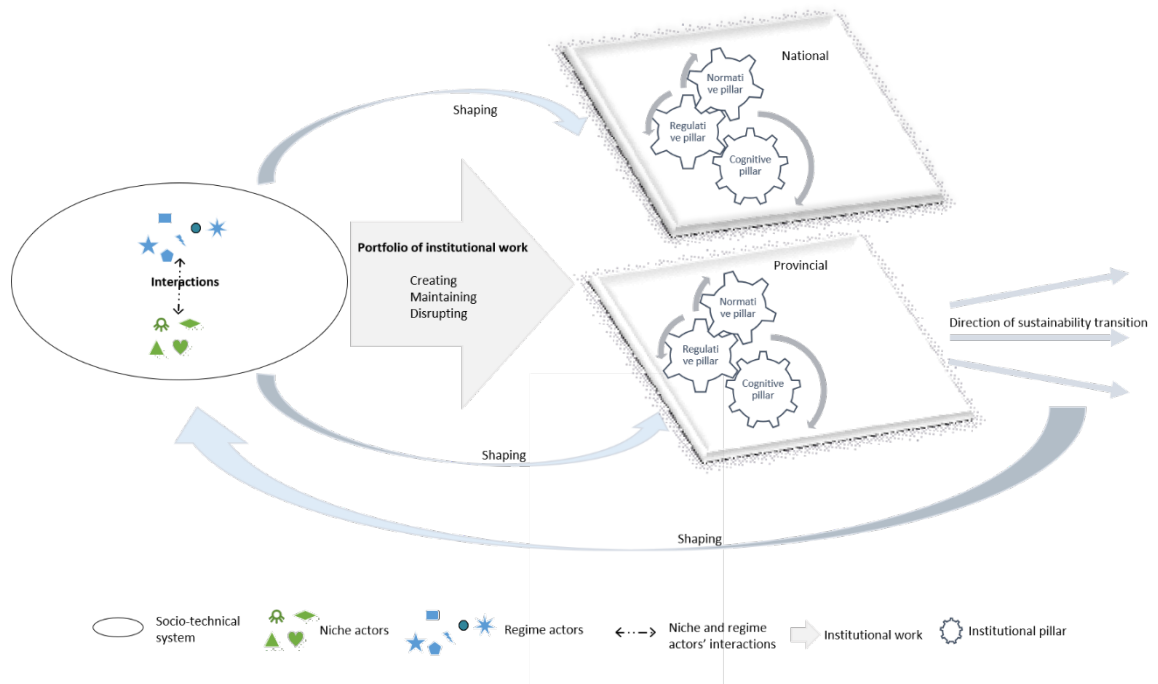


Figure 5.7. Actors adopt portfolio of institutional work shaping directionality of sustainability transitions

## 5. 6 Conclusion

This paper aims to investigate how institutional work adopted by niche and regime actors shapes the directionality of sustainability transitions in terms of fit-and-conform and stretch-and-transform patterns. Based on two strands of literature, sustainability transitions and institutional work studies, we have developed a more symmetrical analysis of niche and regime actors' interactions. Instead of assuming the conventional niche actors oriented niche development and regime actors resist to change, we trace how niche and regime actors adopt different portfolios of institutional work to shape the process of socio-technical change. Moreover, we develop a more spatially sensitive concept of multi-scalar institutional work to capture how niche and regime actors shape regional divergent directions of sustainability transition. The paper led to the formulation of four general propositions that have crucial policy implications. The policies aiming for more transformative change should nurture more heterogeneous actors to work collectively to shape institutional change across all three institutional pillars. Especially our studies indicate the build-up of shared visions across niche and regime actors is key, and when these shared visions allow for a leading role of niche actors combined with openings for new roles and identities of core regime actors, the emergence of a stretch-and-transform pattern is more likely.

We suggest these four propositions can be tested in follow-up studies. More comparative case studies could be conducted to be able to build a comprehensive overview of types of institutional work that are mobilised for a variety of contexts and systems. This study focused on the specific Chinese solar PV case. In general, the type of institutional work, the role of niche and regime actors and how the multi-scalar works out may be different in other socio-technical systems and contexts. Moreover, our studies indicated that sustainability transitions literature could also contribute substantially to the institutional work literature. Future studies could develop a systematic review of institutional work employed by actors in the field of sustainability transitions studies. This could complement the listed institutional work identified in the field of institutional theory in organisational studies, on which this paper is based.

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## Chapter 6 Discussion and conclusion

This chapter discusses the findings of this thesis in the context of the broad literature on sustainability transitions studies. It provides a synthesis of the findings of the three preceding chapters published or submitted as journal articles and discusses their combined contributions to the research aims. A brief summary statement of my novel theoretical contribution is the following: in this thesis I specify how niche and regime actors interact to shape niche acceleration. I am focusing on niche acceleration as it is the phase in which sustainability transitions are speeding up and acquire their directionality. The thesis identifies three main mechanisms for how niche and regime actors interact to shape niche acceleration: expectation alignment, niche shielding and institutional work. Subsequently, it overcomes the conventional bias of niche actors driving the transition process while regime actors resist change. Rather, this thesis argues that a strong alignment and shared agenda between niche and regime actors' expectations contributes to accelerate niche development (rapid speed), and if niche actors are leading in this collaboration with regime actors in distributed institutional work it will take a more radical directionality (called a stretch-and-transform pattern).

Section 6.1 introduces how the research questions are addressed and summarises the key research findings of the three main chapters 3–5. Section 6.2 identifies a number of conceptual, methodological and empirical contributions to the sustainability transitions literature across the three chapters. Section 6.3 discusses the limitations of the research findings. Section 6.4 introduces future research avenues based on this study's research insights. Section 6.5 concludes with final thoughts on the research topic of niche and regime actors' interactions for niche acceleration.

### 6. 1 How research questions are addressed and key research findings

In this section I will elaborate how the synthesis of chapters 3–5 addresses the overall research question and sub-questions.

The thesis aims to address the following main research question: *how do the interactions between niche actors and regime actors shape wind and solar power niche acceleration in China's electricity socio-technical system from 2000 to 2018?*

This main question is divided into three sub-questions, each of them addressing a mechanism for how niche–regime interactions shape niche acceleration. The three sub-questions are:

- 1) How do the alignment dynamics between niche actors and regime actors unfold during niche development? And in particular how do their alignment dynamics shape niche acceleration?
- 2) How do niche and regime actors interact to shape niche shielding dynamics?
- 3) How do niche and regime actors interact to shape the directionality of sustainability transitions?

I will first describe how the thesis answered each of these sub-questions in turn. To address the first sub-question, instead of emphasising regime actors' resistance, Chapter 3 acknowledges the crucial role of strategic support from regime actors for niche acceleration. Niche actors need political power, finance and other resources to help niches stabilise and/or grow. They generally achieve this through collaboration with regime actors, who are powerful actors usually in possession of complementary assets. This leads the chapter to focus on the alignment dynamics between niche and regime actors. However, the two have been characterised as embedded in different selection environments (niche and regime) and unlikely to build strategic collaborations for the purpose of niche acceleration since this may hurt the core business of regime actors. Based on insights from the sociology of expectations and sustainability transitions, the chapter argues that expectations play a crucial role in shaping these alignment dynamics. It develops a novel conceptual framework which proposes three different alignment patterns between niche and regime actors' expectations: *strong*, *medium-strong* and *weak* alignment. Following insights from SNM studies, the chapter develops a measure for the alignment between niche and regime actors' expectations from two aspects: the *breadth* of alignment and the *depth* of alignment. The former concerns how many niche and regime actors are aligned, while the latter interprets depth as alignment of expectation across the three MLP levels of niche, regime and landscape. In other words, if niche and regime actor converge in their expectations about future developments on all three levels, their alignment is deep. This conceptualisation is a basis for a systematic mapping process of the three alignment patterns.

To evaluate how the three alignment patterns relate to niche development, the chapter proposes an innovative threshold for measuring the different phases of niche development, building on innovation diffusion literature. Although innovation diffusion studies examine the diffusion of technology products, which are different from system transition (which involves the introduction of new practices and rules), their insights are still valuable and relevant for measuring niche development. This is reflected in the fact that diffusion curves are often adopted in sustainability transition studies to indicate the different phases of transition. The

chapter proposes a 16% adoption rate of niche technology as a threshold for niche acceleration because when a threshold of 16% is reached innovation diffusion studies have shown that users adopting a new technology are more inclined to follow a social norm, i.e. adopt a new technology because others are doing so. This may be taken as a sign of stabilisation of niche rules since actors do not explore new rules but accept them. The work of Rogers (2010) leads me to propose the following three niche development phases: *pre-development* phase (slow niche development) when the market share of niche technology is below 2.5 % (group of innovators), *take-off* phase (moderate niche development) when the market share is between 2.5 % and 16 % (group of early adopters), and *niche acceleration* phase (substantial niche development) when the market share is above 16% (moving into the group of early majority). This step enables me to test whether and how the proposed three alignment patterns between niche and regime actors' expectations (weak, medium-strong and strong alignment) can be paired to the slow, moderate and substantial niche development.

The chapter applies the conceptual framework for two cases: wind and solar power development in China at the national level between 2000 and 2017. The two cases are selected as they have encountered rapid niche development over the past decade, but in different ways (phases do not converge at the same time). To specify the conceptual framework, the market share of annual new installed capacity of wind and solar power is adopted as the appropriate indicator to divide different stages of niche development because this indicator automatically includes indirectly the market share of competitors (other niches) and the decline of the dominant coal power regime too. Hence it provides a very good indicator of the strength of the niche under study. It then specifies who are the niche and regime actors for the development of wind and solar niches in China's electricity system, and indicates which actors need to be aligned in order to conclude for a medium-strong alignment pattern. To identify the alignment dynamics between niche and regime actors in the two cases, the chapter develops a semi-quantitative mapping tool. This mapping tool specifies how actors' expectations can be studied for the different regime dimensions of the socio-technical system (S&T, political, industry, market and culture) and across three different levels (niche, regime and landscape). It uses a mixed method approach to collect data and allow triangulation. To be specific, it makes use of 31 semi-structured interviews, 6 informal interviews, a workshop and secondary data. The chapter employs comparisons *across* and *within* cases to investigate how niche and regime actors' alignment dynamics of expectations shape niche development. Chapter 3 concludes that strong alignment between niche and regime actors' expectations in China on wind and solar power



between 2000 and 2017 is a good predictor for niche acceleration. Here I focus on the speed of niche development not its directionality.

To address the second sub-question, Chapter 4 contributes to developing further understanding of the underdeveloped but core concept of niche shielding in SNM studies. The chapter investigates how niche and regime actors interact to shape niche shielding dynamics. It argues that existing SNM studies generally treat niche construction as a simple linear process with a phase of building up a temporary protective space and then phasing this out. It neglects two crucial aspects of niche shielding dynamics: (i) for successful niche development, shielding has to hold off selection pressure from multiple dimensions of the socio-technical system; and (ii) shielding dynamics are shaped by the interactions of shielding across a range of levels and scales (local, provincial, national and global). It develops a research framework to investigate how niche and regime actors interact to shape niche shielding dynamics from multiple regime dimensions and across multiple spatial scales.

The chapter examines two contrasting cases, wind power development in Inner Mongolia and Jiangsu province, in the context of national scale development, between 2000 and 2017. The case of Inner Mongolia shows rapid wind power development fitting into the existing centralised power system, while the case of Jiangsu shows relatively moderate wind power development with a potential to transform the existing centralised power system. It traces historical events to construct the storyline of niche shielding dynamics for wind power development in the two provinces. The analysis draws on data collected from multiple approaches including several primary data sources (interviews and a workshop) as well as secondary data so that they can be triangulated. Interview data were collected from two rounds of fieldwork, from October 2017 until March 2018, and in January 2019. The data analysis was carried out in different stages, starting with open coding, to allow empirical insights to emerge beyond the theory to fully explore how niche and regime actors' interactions unfold, and how their interactions shape the two divergent niche shielding dynamics.

The research findings indicate that niche and regime actors' interactions involved in shielding are complex processes. They may align in certain regime dimensions while conflicting in other dimensions across multiple scales. The empirical analysis in the chapter confirms that niche construction process is more complex than the previous SNM studies assumed. It is not a linear process which first enacts temporary protection and then phases this protection out step-by-step. The chapter argues that to understand the phasing-out process the analysis must examine how niche shielding dynamics coordinate across multiple dimensions and multiple scales. The lack of coordination is a crucial constraining factor for the speed of niche development. For

example, the lack of coordination between central government, grid companies and local governments have constrained the rapid diffusion of wind power in China. Moreover, the research insights also indicate that while the shielding from regime actors can contribute to rapid niche development, it may constrain the niche development from moving in a more radical direction. For example, in 2007 when the central government encouraged the development of large-scale wind farm sites adding impulse to the rapid deployment of wind power, it also had another impact: it led to less radical system transformation measured in terms of a fit-and-conform pattern, i.e., the large-scale wind power fits and conforms with the existing centralised power systems with long-distance transmission lines. Thus, in this case speed came at the expense of more radical change.

Finally, to address the third sub-question, how niche and regime actors shape the directionality of niche development, Chapter 5 unpacks how they interact by building up a specific portfolio of institutional work. Instead of assuming that radical socio-technical change is driven by extreme events, or that a transformation of regime only occurs when pressure from the landscape is combined with challenges coming from niche development, as is argued in the MLP, the chapter argues that radical socio-technical system change is a result of institutional work distributed among different actors working across different MLP layers and spatial boundaries (multiple geographical scales). Following recent insights from sustainability transitions studies and institutional theory, transition can be conceptualised as an intertwined process of institutionalisation (niche stabilisation) and de-institutionalisation (regime destabilisation). The chapter argues, therefore, that directionality of niche development is the outcome of actors' interactions to create (niches), maintain or disrupt institutions (regimes). This concept of institutional work enables the chapter to open up the black box of institutional change and to trace how niche and regime actors interact to either create, maintain or disrupt institutions. Another key contribution of the chapter is developing the concept of multi-scalar institutional work. It is conceptualised to show how regional actors can shape institutions at the national level or selectively interpret national level rules.

The chapter investigates two contrasting cases: solar PV development in China's two provinces, Inner Mongolia and Jiangsu from 2000 to 2018. The former has developed large solar PV power plants fitting into the centralised electricity grid, while the latter exhibits a more decisive development of decentralised, micro-grid integration of the same technology. These two patterns represent two divergent directions of niche development, i.e. a fit-and-conform and a stretch-and-transform pattern respectively (Smith and Raven 2012). The chapter argues that the chosen pattern depends on the type of institutional work that actors enact, according to three

key aspects: (1) The portfolio of institutional work making distinctions between creating (aiming for niche creation), maintaining (aiming for regime maintenance) and disrupting (aiming for regime destabilisation), and whether the work addresses all three institutional pillars covering regulative, normative and cognitive rule sets. The distinction of three institutional pillars draws on the work of Scott (1995). The regulative pillar refers to formal rules, such as laws, government policies and regulations; normative rules refer to values and social norms; and cognitive rules refer to beliefs and symbolic meanings. (2) The nature of niche–regime interactions. Here the chapter focuses on whether niche actors play a leading role in shaping institutional change working with regime actors, or regime actors play a leading role and are in the position to ignore the disruptive institutional work of niche actors. (3) The multi-scalar dimension of institutional work. This concerns the question of how actors mobilise institutional conditions across provincial and national scales. The overall research findings suggest that directionality will be more radical (stretch-and-transform pattern) when niche and regime actors (i) perform a broad portfolio of institutional work that addresses regulative, cognitive and normative pillars that constitute a regime; (ii) collaborate in a process led by niche actors but with involvement of regime actors who share expectations; and (iii) leverage windows of opportunity provided by their provincial and/or national contexts. In other words when they engage in multi-scalar activities.

The combined insights from the three main chapters therefore shed light on the overall research question by identifying three key mechanisms of how the interactions between niche and regime actors shape niche acceleration. As concluded in Chapter 3, the strong alignment between niche and regime actors' expectations is a precondition for niche acceleration (rapid niche development), while the directions of niche development depend on the process of how these two interact through different types of institutional work, as discussed in Chapter 5. Chapter 4 discusses the trade-off between rapid speed and radical directions through unfolding the niche shielding mechanism.

## 6. 2 Main contributions of the thesis to knowledge

Having discussed how the three chapters answer the research questions, this section will specify a number of general contributions to the sustainability transitions literature across these three chapters. They will be categorised and discussed in turn as conceptual contributions (section 6.2.1), methodological contributions (section 6.2.2) and empirical contributions (section 6.2.3).

### 6. 2. 1 Conceptual contributions

This study first makes conceptual contributions to the field of sustainability transitions, in particular to two dominant frameworks, MLP and SNM, and also to the geography of sustainability transitions literature, and to the sociology of expectations and institutional work literatures.

I will start with elaborating how this thesis contributes to MLP and SNM studies, which are the two main theoretical conceptual frameworks this thesis draws on.

First and foremost, the thesis responds to criticism that the MLP ignores the role of agency with too much descriptive and structural analysis (Smith et al., 2005; Genus and Coles, 2008). This thesis specifies three key mechanisms to explicitly conceptualise how niche and regime actors interact to shape transition dynamics: expectations alignment, niche shielding and institutional work enacting. By doing this, it overcomes the conventional understanding of the clear-cut strategies adopted by niche and regime actors for socio-technical change, i.e. niche actors contribute to create niches, while regime actors generally prefer to stabilise regimes and resist niches.

To elaborate, building on insights from sociology of expectation studies, the thesis argues that expectations play a role as an ex-ante selection environment to shape the prospective socio-technical structures. Actors pursue changes driven by their expectation dynamics. As argued in Chapter 3, strong alignment between niche and regime actors' expectations contributes to niche acceleration. However, arriving at such alignment can be challenging because niche and regime actors generally hold divergent interests, values and mindsets. A key contribution of the thesis is the claim that it is precisely the mechanism of building up shared expectations between niche and regime actors that promotes overcoming the divide between the two type of actors. Evidenced further by Chapter 5, shared visions between niche and regime actors are most crucial for changing the cognitive support of a possible new regime structure, including the relative identities and roles that the different actors would hold in them. As suggested in the case of Jiangsu, when the vision of a more localised energy system with a low-carbon and green energy sector was widely supported by society, both niche and regime actors identified solar PV as an important trail blazer on the way to such a system. This provided a solid basis for niche and regime actors to collaborate on shielding a wide number of local experimentations to fulfil this expectation.

Building on institutional work studies, the thesis contributes to the understanding of how niche and regime actors interact to shape the change of institutions. This contribution responds to the

criticism that MLP holds a bias of treating regime transformation as driven either by landscape pressure or niche challenges or both. In addition, SNM and MLP frameworks have been criticised that they pair a fit-and-conform pattern with a bottom-up, niche-driven process, and thus assume niche actors are responsible for “fit to” or “stretch of” the regime. This thesis overcomes this bias and argues that transition dynamics are a result of interactions between niche and regime actors to either create (niche development) or maintain (regime stabilisation) or disrupt (regime destabilisation) institutions. The thesis concludes that the collaborated and distributed institutional work of niche and regime actors shapes the directionality of niche development. Regime actors can either mobilise niches to further consolidate the legitimacy of regime, which leads to less radical niche acceleration, or they can contribute to transforming the regime by investing in niche development (radical niche acceleration).

To summarise, by specifying the three mechanisms of how niche and regime actors interact to shape transition dynamics, this thesis responds to scholars’ criticism that SNM and MLP hold a bias that niche actors drive changes as they are more innovative, and that regime actors are resistant to changes as they are embedded into the entrenched socio-technical structures. The thesis argues that to accelerate niche development requires strategic alignment between niche and regime actors, and this is driven by the interactions of their expectations. Moreover, it argues that both niche and regime actors play a proactive role and can enact any types of institutional work (creating, maintaining and disrupting) to shape the process of institutional change.

In addition, this thesis contributes to both SNM and MLP by advancing the understanding of how niche–regime interactions shape both rapid and radical niche development. Although MLP contributes to our understanding of how transition dynamics unfold with interactions across multiple layers (niche, regime, landscape), there is still limited understanding of how niche–regime interactions evolve, and how their interactions contribute to niche acceleration. SNM advances our understanding of how niches can be constructed through three mechanisms (expectation articulation, network building and learning) to nurture radical directions; however, there has been limited understanding of how to accelerate the rapid diffusion of niches. In summary, there is still limited understanding on how to achieve both rapid and radical niche development. This is evidenced by the debate that was introduced in section 1.1, which has been a motivation for conducting this research. This thesis contributes to the study of niche acceleration by specifying two aspects of niche development: its speed and its direction.

This thesis advances the understanding of the speed aspect. It argues that the strong alignment between niche and regime actors’ expectations can be seen as a good predictor of niche

acceleration (rapid niche development). This thesis also advances understanding of the direction aspect of niche development. Building on institutional work studies, this thesis advances our understanding of which actors are doing which type of institutional work (either creating, maintaining or disrupting, whether addressing regulative, normative or cognitive pillars), and how this influences the directionality of sustainability transition (either to fit-and-conform or stretch-and-transform niche development pattern).

This thesis also makes specific contributions to MLP and SNM. It responds to the criticism that MLP holds a homogeneous understanding of the regime by refining it from two aspects, dimension and scale. The thesis unpacks the socio-technical regime as consisting of five different dimensions (science and technology, industry, market, policy, and culture) and across multiple scales (provincial and national). Following this insight, the thesis contributes to developing an underdeveloped concept in SNM studies, niche shielding. A key claim in this thesis is that niche shielding dynamics need to be studied from these two aspects: (i) how niches shield against selection pressure from multiple regime dimensions; and (ii) how niche shielding unfolds across multiple scales. This makes niche construction processes much more complex than is often assumed by SNM studies, which regard a linear understanding of first enacting niche protection and then phasing out step-by-step. Instead, this thesis finds that niche shielding may coordinate among some dimensions while conflicting in other dimensions across multiple scales. Therefore, this thesis argues that when phasing out niche protection it is crucial to examine how niche shielding coordinates with these two aspects.

This thesis also contributes to the geography of sustainability transition studies by developing the multi-scalar dimension of niche–regime interactions. Most of the geography studies of sustainability transitions articulate how the institutional context contributes to the emergence of niches while few studies have articulated the multi-scalar dimension of socio-technical regime. This thesis considers a multi-scalar understanding of socio-technical regimes, which has been conceptualised as multi-scalar structures with rules that may be interpreted by regional actors in their local contexts (resulting in regional implementation styles of national regulations). Moreover, this thesis contributes to the geography of sustainability transitions by advancing our understanding on how different regions enact divergent niche development patterns. It argues that regional actors can enact institutional work across multiple scales to shape institutional change to support their preferred niche development patterns.

By drawing on sociology of expectation literature and institutional work literature this thesis also contributes to these strands of literature. Following insights from MLP, the thesis expands the understanding of actors' expectation dynamics for radical innovations in the sociology of

expectations literature. It goes beyond the original understanding that predominately focuses on niche development and, instead, it incorporates actors' expectations of regime resilience in responding to external crisis and internal tensions, and also actors' expectations of landscape development. In summary, this thesis argues that the interactions of niche and regime actors' expectation dynamics of three layers (niche, regime and landscape) shape the transition dynamics towards prospective socio-technical structures.

This thesis also makes conceptual contributions to institutional work studies. The thesis generates useful insights on how actors team up to shape more radical institutional change. Institutional work generally conceptualises how actors collectively and proactively adopt different types of strategies to shape institutional change, while there is less discussion of what types of actors build constellations, enacting what types of institutional work shape more radical institutional change. This thesis argues that institutional change depends on the types of institutional work actors enact (i.e. the portfolio of institutional work) and who are the actors enacting these types of institutional work (the nature of niche–regime interactions). As evidenced in Chapter 5, different actors may enact the same types of institutional work for different purposes. This study argues that institutional change occurs with interactions among heterogeneous actors who are embedded in different institutional structures. Actors adopting a portfolio of institutional work addressing all three different institutional pillars and the process led by niche actors who are peripheral to dominant institutions (regime) will more likely result in more radical institutional change.

Moreover, this thesis contributes to institutional work studies by arguing that shared expectations are crucial to guiding collective actions among actors to shape more radical institutional change. The crucial question that existing institutional work studies have not addressed is under what conditions actors are embedded into existing institutions, and under what conditions actors actively shape institutional change. The study on the social dynamics of expectations suggests a potential explanation that when niche and regime actors build shared visions, they are more likely to adopt institutional work to shape more radical institutional change.

Finally, the thesis contributes to developing an understanding of the multi-scalar dimension of institutional work, which contributes both to institutional work studies and to the geography of sustainability transition studies. At the time of writing, institutional work literature has not drawn attention to the geographical perspective of actors' institutional work. The geography of sustainability transition studies has also not drawn attention to actors' institutional work. This thesis advances this understanding by integrating insights from these two strands of literature.

This thesis argues that actors adopt multiple types of institutional work to shape institutional change across multiple scales. Especially, it suggests actors are not just intentionally mobilising institutional conditions at national level, but they can also proactively shape institutional change at the national level. Understanding the multi-scalar dimension of institutional work offers insights into understanding both constraints and opportunities for actors to shape institutional change at certain scales. In summary, the identification of the multi-scalar dimension of institutional work recognises the windows of opportunity for local actors to shape institutional change at multiple scales to achieve their locally preferred patterns of institutional change.

### 6. 2. 2 Methodological contributions

The thesis makes three specific methodological contributions.

First, the thesis offers a quasi-quantitative method to measure different alignment patterns between niche and regime actors' expectations. As discussed in Chapter 3, this novel methodology allows other researchers to trace and investigate how niche and regime actors' alignment dynamics unfold, especially to map out how their alignment patterns relate to niche development.

Second, the thesis offers a way to measure niche acceleration. Building on innovation diffusion studies, the thesis uses technology diffusion rate as an indicator to measure different stages of niche development. To be specific, the thesis proposes that when the adoption rate of a new technology is below 2.5%, this is the pre-development phase. When the adoption rate is between 2.5 % and 16 %, this is the take-off phase, and when the market share is above 16%, it is the niche acceleration phase. This measurement is particularly useful for transition scholars who study the speed of niche development.

Third, this thesis makes a novel methodology contribution by offering a way to measure how actors adopt a portfolio of institutional work to shape the socio-technical system transformation. Specifically, it categorises institutional work as a portfolio by examining two axes: institutional pillars (regulative, normative or cognitive) and types of institutional work (creating, maintaining or disrupting). This model for measurement can be used by other researchers to study how different actors interact and enact different types of institutional work to shape the divergent directions of niche development.

### 6. 2. 3 Empirical contributions

This thesis makes specific contributions to understanding why wind and solar power developed rapidly in China from a socio-technical system perspective. In particular, the study offers detailed accounts of interaction patterns between different stakeholders in terms of their



alignment of expectations, niche shielding and types of institutional work enacting to shape this process. Moreover, it examines wind and solar power development between 2000 and 2017 at national and provincial level (focusing on Inner Mongolia and Jiangsu). This focus offers rich empirical insights on why the two provinces have divergent niche developments that have been far less understood.

The key findings of the thesis suggest that the rapid development of China's wind and solar power cannot be attributed to one specific actor, such as the state, but needs collective actions among different stakeholders, especially alignment dynamics between niche and regime actors. This has been illustrated and explained throughout the whole thesis. This understanding contrasts with the dominant story that has been told in the existing studies, which has defined China's rapid wind and solar power development as a state-led process by regulating the market and protective support for technological innovations (see the review by Shen and Xie (2018)). As concluded in Chapter 3, this thesis argues that the rapid wind and solar power development in China connects with the alignment dynamics between niche and regime actors' expectations. The detailed historical account of interaction dynamics between different stakeholders illustrates that the incumbent actors played crucial roles in accelerating the rapid deployment of wind and solar power in the past two decades. In particular, the intensive involvement of big state-owned enterprises in investing in RE offers momentum for the rapid diffusion of wind and solar power development. However, this investment momentum is strongly shaped by changes in the policy environment and concerns about domestic environmental issues and climate change. In sum, the process is driven by the reconfiguration process of different socio-technical elements through the interactions between niche and regime actors.

The above state-led understanding is further challenged by the critical role that local actors have been playing in shaping divergent development patterns of wind and solar PV, which has been evidenced in the two provinces. Local actors in Inner Mongolia and Jiangsu adopt multiple strategies of institutional work proactively shaping their locally preferred directions of niche development. In the case of solar PV, the two provincial actors not just intentionally mobilise national level institutional conditions but also proactively shape institutional change at national level. This leads to a divergent niche development pattern in two provinces. Moreover, provincial actors can also shape the divergent transition pathways from what is pursued at the national level. For example, the well-developed distributed solar PV system in Jiangsu province is largely shaped by the diverse experimentations of local actors and coalition building between different actors. This niche development pattern divergence between provincial and national level illustrates the complex state-provincial dynamics for low-carbon transition in China. This

complexity is also evidenced by the lack of coordination of niche shielding dynamics across provincial and national level in the case of wind power. The lack of coordination between provincial and national level has been demonstrated in different ways. For example, the national and provincial actors adopt different visions of renewable energy in the future energy system.

Overall, the thesis advances the understanding of a complex picture of low-carbon transitions in China's electricity socio-technical systems, which unfolds with interactions among different actors across provincial and national scale. This complexity is not just illustrated by the complex state-provincial dynamics but also evidenced by the multitude directions of niche development that have been observed across different provinces. In summary, the detailed studies of provincial differences and state-provincial dynamics in China make significant empirical contributions to existing knowledge.

### 6.3 Qualifying the scope of the conclusions

I have so far generalised my research findings and contributions from cases that present geographical, historical and sectoral specificities. The research findings thus have to be qualified so that they can be mobilised in further research. Therefore, here I will discuss how the specific country focus on China, the electricity socio-technical system and the specific historical period (2000–2017) may influence the scope of the conclusions of this study.

The cases are limited to the specific geographical scope of China. The country's specific political and economic landscape may influence the interaction patterns between niche and regime actors. China is considered to be an authoritative state, where the state has a strong influence over niche and regime development, thus shaping the interaction patterns between niche and regime actors in a specific way. The cases of wind and solar power development in China have illustrated the successful role that forward-looking policy can play in shaping incumbent actors' expectations, of course with the caveat that this policy is subject to lobbying by provincial actors and/or can be interpreted by them in many ways, as Chapter 5 shows. Although struggles between the state and other actors, such as provincial governments and big utilities, have been observed in the low-carbon transition process of China's electricity system (as chapters 3 and 4 show), it is difficult to deny that the central government's strong determination to shape the electricity system as clean and low carbon has largely nudged coal power incumbents towards RE. Moreover, the central government's push of the grid company towards supporting renewable energy, and its determination to push for liberalisation-oriented reforms of the electricity system exerts pressure on the grid company towards more innovative solutions and embracing the low-carbon transition. This thesis acknowledges the specific role of the state in

China in shaping the interaction dynamics between niche and regime actors for the wind and solar power niche acceleration in China's electricity socio-technical systems.

Moreover, China has experienced rapid economic growth over the past three decades, accompanied by a rapid expansion of electricity demand. This rapid economic growth may have a specific influence on niche–regime interactions. For example, as discussed by Shen and Xie (2018), in the early stage (before 2014), there was limited resistance from regime actors as they could gain benefits from both renewable energy and coal power. This has been also observed in this thesis. The rapid electricity demand makes the development of RE and coal power not a zero-sum competition but a win-win strategy of conventional power investors. This early stage of the win-win period offered spaces to nurture renewable energy development to be established in China's electricity socio-technical system before it encountered fierce resistance from coal power regime actors. As discussed in Chapter 4, after 2014 more struggles were observed between thermal power and RE, especially at the provincial level.

#### 6. 4 Underdeveloped themes and avenues for future research

Reflecting on the research findings of the three main chapters, there are several potentially fruitful avenues for future research.

A first research avenue could explore the generalisation of the conclusion that strong alignment between niche and regime actors' expectations is a precondition for niche acceleration. As discussed in the previous section, the conclusions of this thesis mainly build on the empirical insights from two cases, wind and solar power development in China's electricity system. This argument could benefit from expanding the analysis to different political and economy systems. The case of China has indicated that the specific relationship between the state and business in the electricity socio-technical system may contribute to translating actors' expectations into concrete activities to support niche development. It would be interesting to examine how expectations play a role in guiding actors' activities in other institutional arrangements, especially if comparative cases across countries could be conducted to test the generalisation of this conclusion.

A second research avenue concerns the generalisation of the conceptual framework proposed by Chapter 5. Chapter 5 argues that three aspects are key in understanding how actors interact to shape the directionality of transition dynamics: the portfolio of institutional work enacted by actors; the nature of niche and regime interactions; and how actors mobilise institutional conditions across multiple scales. The chapter suggests four propositions that can be tested through future studies. Moreover, future researches could also investigate how these three

aspects co-evolve during the process of socio-technical change. The adoption of process theory would suggest some potentially useful insights.

The third idea for future research is the relationship between actors' expectations and the institutional work that actors enact. Literature on social dynamics of expectations articulates that expectations guide actors' activities. Institutional work involves the types of activities and strategies that actors mobilise to shape institutional change. It is thus worthwhile to explore to what extent actors' expectations could be translated into the types of institutional work shaping socio-technical change. This research avenue could certainly be advanced by bringing together the two strands of literature, institutional work studies and social dynamics of expectations studies.

## 6. 5 Concluding remarks: escaping the past and moving towards a desired future

To conclude this thesis, I will respond to the open question raised in the introduction of how to accelerate radical innovation towards more sustainable directions, i.e. how to achieve both rapid and radical niche development.

The thesis argues that niche acceleration does not just depend on niche actors who hold visions to reimagine a new sustainable socio-technical system. Regime actors could play a key role as well. As discussed by several scholars previously, there is no lack of assets, knowledge and resources for transformative innovation at the global scale (Mazzucato and Perez, 2015; Jacobs and Mazzucato, 2016; Perez, 2016). The difficulty is in mobilising these assets (Fagerberg, 2018). In most cases, these assets are held by incumbent (or regime) actors. It is crucial to mobilise these incumbents to move towards sustainable development. However, the key is how to turn incumbent actors towards a desirable future. As John Maynard Keynes argued, the difficulty lies not so much in developing new ideas as in escaping from old ones (Keynes, 2018).

This thesis offers some useful insights on how to escape the old pathways and move towards the desired future through unpacking the interaction dynamics between niche and regime actors. Instead of treating regime actors as homogeneous actors who always resist change, this study argues it is crucial to unpack the conditions under which those actors overcome the system lock-in and start to collaborate with niche actors for the purpose of niche acceleration. The thesis specifies three key mechanisms: expectations alignment, niche shielding and institutional work. Two key points are valuable: (1) It has become obvious that shaping incumbent actors' expectations and building a strong alignment of expectations with new entrants so that they can collectively shape the prospective socio-technical structures would contribute towards escaping old pathways; and (2) actors can enact different types of

institutional work and mobilise institutional conditions across multiple scales to shape institutional change towards desired directions. Institutionalising niches through an intentional steering process led by niche actors is perhaps the way to move towards a more desirable and sustainable future.

Moreover, the thesis concludes that innovation policy could play a crucial role in stimulating transition processes through building shared expectations between niche and regime actors. As identified in Chapter 3, policy is not just shaped by actors' expectations, but it also shapes actors' expectations. What is obvious from the two cases of wind and solar power development in China is that national policy could play an active role as a bridge to connect regime actors' expectations towards specific niches and thus can contribute to the acceleration of these niches. This resonates with the argument made by Fagerberg (2018) that incumbent actors such as large firms "are reluctant to move into new areas because they are uncertain about the future prospects. One of the most effective policy instruments that innovation policy makers can use to remedy this problem is to influence firms' expectations about the future, that is, setting direction" (p. 1573).

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## Appendices

### Appendix A List the interviewees, focus group and workshop participants

Table A.1. List of the interviewees with illustration of distribution across Chapters 3-5.

Categories	Organizations and position	Numbers	Date, venue	Distributions across chapters 3-5
State Grid company	Energy research institute of State Grid Corporation of China (SGCC), Researcher	1	18 Nov. 2017, Beijing	Chapters 3-5
State Grid company	Strategic Planning of State Grid Corporation of China (SGCC), Research fellow	1	7 Jan. 2018, Beijing	Chapters 3-5
State Grid company	Renewable Energy research institute of State Grid Corporation of China (SGCC), Director	1	3 Feb. 2018, Beijing	Chapters 3-5
Central government	National Development and Reform Commission (NDRC), Policymaker	1	10 Nov. 2017, Beijing	Chapters 3-5
Central government	Energy Research Institute, NDRC, researcher	1	14 Nov. 2017, Beijing	Chapters 3-4
Central government	Former policymakers in the energy sector	1	12 Dec. 2017, Beijing	Chapters 3-4
Central government	Renewable energy research centre, research institute of NDRC, Director	1	14 Dec. 2017, Beijing	Chapters 3-5
Electric power generators	China Energy Investment Corp., Director of Strategic Planning office	1	1 Dec. 2017, Beijing	Chapters 3-5
Electric power industry	China Electricity Council, Secretary General	1	10 Jan. 2018, Telephone	Chapters 3-5
Renewable energy generator	China Longyuan Power Group Limited, Managers and investors (three experts)	3	22 Oct. 2017, Beijing	Chapters 3-5
Renewable energy generator	China General Nuclear Power Group (CGN), Investor and manager	1	4 Nov. 2017, Beijing	Chapters 3-5
Electric power generator	Shanghai Electric Power Company, Regional manager	1	21 Dec. 2017, Nanjing	Chapters 3-5
Energy Research Institute	Chinese Academy of Sciences, decentralised energy system researcher & policy consultancy and directly involved into policy making;	1	18 Nov 2017, Beijing	Chapters 3 and 5
Energy Research Institute	Chinese Academy of Sciences, decentralised energy system researcher & storage technology	1	12 Jan 2018, Beijing	Chapters 3 and 5
Wind power manufacturing industry	Xinjiang Goldwind Science & Technology Co., Ltd., Regional manager in Jiangsu	1	6 Jan. 2018, Nantong	Chapter 4

Wind power manufacturing industry	Sinovel Wind Group Co., Ltd., Regional manager in Jiangsu	1	6 Jan. 2018, Nantong	Chapters 3-4
Wind power manufacturing industry	Envision Energy wind power research center, Denmark, Technical researcher	1	20 Jan. 2019, Skype	Chapter 4
Wind power Industry association	Chinese Wind Energy Association (CWEA), Director	1	17 Nov. 2017, Telephone	Chapters 3-4
Wind power Industry Association	Chinese Wind Energy Association (CWEA), Secretary-general	1	23 Dec. 2017, Beijing	Chapter 4
Wind power Industry Association	Technological expert and CEO in big wind power manufacturing company, LM Wind Power	1	17 Aug. 2017, Netherlands	Chapter 3
Inner Mongolia	Local government, Former director of renewable energy policy	1	7 Mar. 2018, Beijing	Chapter 4
Inner Mongolia	Wind power industry association, Secretary-general	1	23 Dec. 2017, Beijing	Chapter 4
Inner Mongolia	Grid company, Director and manager	1	7 Mar. 2018, Beijing	Chapter 4
Inner Mongolia	Renewable Energy industry association of Inner Mongolia, Secretary-general	1	22 Jan 2019, Hohhot	Chapter 5
Jiangsu province	Local government official of renewable energy development	1	20 Dec. 2017, Nanjing	Chapters 4-5
Jiangsu province	Renewable Energy industry association, Secretary-general	1	21 Dec. 2017, Nanjing	Chapter 4
Jiangsu province	Renewable Energy association of Jiangsu province	4	22 Dec 2017, Nanjing	Chapters 3 and 5
Jiangsu province	Electric power industry association of Jiangsu province	1	10 Jan 2018, Telephone	Chapter 5
Jiangsu province	Grid company	1	21 Dec. 2017, Nanjing	Chapter 4
Jiangsu province	Solar power industry association of Jiangsu province, Secretary-general	1	21 Dec 2017, Nanjing 8 Jan 2019, follow up	Chapter 5
Jiangsu province	Trina Solar- strategic development experts	1	10 Jan 2019, Changzhou	Chapter 5
Wind power manufacturers	Xiangtan Electric Manufacturing Co.,ltd, Regional managers	1	21 Dec. 2017, Nanjing	Chapter 4
Renewable energy industry association	Chinese Renewable Energy Industries Association, President	1	22 Dec. 2017, Nanjing	Chapters 3 and 5
International wind power manufacturing industry	Technological experts and managers in big wind power manufacturing company	1	17 Aug. 2017, Netherlands	Chapter 4
Wind power industry association	Global Wind Energy Council, Director	1	24 Nov. 2017, Skype.	Chapters 3-4

Solar PV manufacturing industry	National Laboratory of Trina Solar, Director of S&T and innovation development	1	27 Dec 2017, Telephone	Chapter 5
Solar PV manufacturing industry	Solar PV manufacturing firm on Micro-inverter for Solar PV	1	23 Jan 2018, Beijing; 11 Jan 2019, Shanghai, follow up	Chapter 5
Solar PV manufacturing industry	National Solar PV industry association, Vice Secretary in General	1	23 Jan 2018, Beijing	Chapters 3 and 5
Solar PV manufacturing industry	China Photovoltaic Industry Association (CPIA), Secretary General	1	21 Dec. 2017, Nanjing	Chapters 3 and 5
Solar PV manufacturing industry	Trina Solar- leader on the distributed energy system and storage group;	1	11 Jan 2019, Shanghai	Chapter 5
Solar PV manufacturing industry	Trina Solar- expert on the company's strategic plans;	1	17 Jan 2019, Beijing	Chapter 5
Universities	North China Electric Power University, Researchers on electric power policy and economic analysis	1	Jan. 2019, Beijing	Chapter 4
Universities	North China Electric Power University, Researcher on Solar PV development	1	18 Oct 2017, Beijing	Chapters 3-5
Universities	North China Electric Power University, Researcher on National Grid development	1	27 Dec 2017, Beijing	Chapters 3-4
Universities	Xi'an Jiaotong-Liverpool University, Researcher on renewable energy development	1	31 Dec 2017, Suzhou	Chapter 5
Universities	Tsinghua University, Researcher on renewable energy development (researchers who have conducted different initiatives for solar PV development)	1	29 Dec 2018, Beijing	Chapter 5
NGOs	Greenpeace (2experts on China's coal power policy strategies)	2	16 Oct 2017, Beijing	Chapters 3-5

Table A.2. List of the focus groups for Chapter 5.

Categories	Organizations and position	Numbers	Date, venue	Distributions across chapters 3-5
Jiangsu province	Renewable Energy industry association of Jiangsu province, Decentralised energy system and storage company and experts (solar PV and Renewable Energy in general)	3	8 Jan 2019, Nanjing	Chapter 5

Jiangsu province	Solar PV generator; Distributed solar PV investor and storage company; Big data and Internet of Things- company	3	9 Jan 2019, Nanjing	Chapter 5
Jiangsu province	Local installer company; Local government official from Changzhou, Jiangsu province;	2	10 Jan 2019, Changzhou	Chapter 5
Inner Mongolia	Provincial government, solar PV manufacturing industry association, solar PV investor, Grid company from Inner Mongolia	4	23 Jan 2019, Hohhot	Chapter 5



Table A.3. List of workshop participants in March 2018.

No.	Categories	Organizations and position
1	Universities	Professor on innovation policy studies, University of Nottingham Ningbo China
2	Universities	Professor on energy transition in China, North China Electric Power University
3	Research Institute	Associate Professor, The Administrative Center for China's Agenda in 21 <sup>st</sup> Century
4	Universities	Associate Professor, School of Public Policy & Management, Tsinghua University
5	Research Institute	Research Fellow, National Center for Science & Technology Evaluation
6	Research Institute	Research Fellow, Institute of Science, Technology and Society Development, CASTED
7	Electric power investors	Deputy Director, Tech-economic Strategy Advisory Center, China Energy Investment Corp.,
8	Inner Mongolia Local government	Former Director of New and Renewable Energy centre of Energy Administration of Inner Mongolia
9	Inner Mongolia Electric power association	Vice Secretary-General of Electric Power Association & Secretary-General of Wind Power Association of Inner Mongolia
10	Inner Mongolia solar PV industry association	President of Solar Power Association of Inner Mongolia;
11	Inner Mongolia Grid company	Director of production and technology department, Inner Mongolia Power Co., LTD
12	Research Institute	Director of Institute of Science, Technology and Society Development, CASTED
13	Research Institute	Associate Professor, Institute of Innovation and Industrial Development, CASTED
14	Research Institute	Associate Professor, Institute of Innovation and Industrial Development, CASTED
15	Research Institute	Assistant Professor, Institute of Innovation and Industrial Development, CASTED
16	Research Institute	Assistant Professor, Institute of Innovation and Industrial Development, CASTED
17	Universities	Professor of Innovation and Sustainability at the Policy Studies Institute, University of Westminster, UK
18	Government institute	Director of International Relations & Cooperation at National Research Foundation, South Africa
19	Universities	Former Director and professor, Science Policy Research Unit, University of Sussex, UK
20	Universities	Senior lecturer, Science Policy Research Unit, University of Sussex, UK
21	Universities	Research Fellow, Science Policy Research Unit, University of Sussex, UK
22	Universities	Doctoral researcher, Science Policy Research Unit, University of Sussex, UK

## Appendix B Interview questions

Below are the semi-structured interview questions that have been used to guide for fieldwork. This list has been accommodated according to each interviewee' background (working experiences, types of actors their work represent). These interview questions are translated into Chinese when the respondents are Chinese.

#### General background of the interviewee

1. Can you please tell me about your recent work and your responsibilities?
2. When did you start to get involved into renewable energy, solar and wind power activities/ electric power development in general? And why, what are the motivations?
3. Did you get involved in the two regions (Inner Mongolia and Jiangsu province)? Please can you explain how?

#### Understanding of the reasons behind the rapid increasing installed capacity

4. What do you think are the driving forces behind the fast increasing of installed capacity of wind power in China? Are the driving forces changing over time from 2000 to 2017?
5. Is that driving force similar to that of solar power? And if so, in what way?
6. What are the key historical events which have shaped wind and solar power development, in what ways? and why they are matter?

#### Roles of actors and their strategies and perceptions for socio-technical system transformative change

7. Who are the main actors involved into the solar and wind power development process in China? And how do they change their perceptions and involvement from 2000 to 2017?
8. What is the role of the central/local government in the development of wind and solar power?
9. In your experience, do thermal companies play any role in the development of renewable energy in China? And if so, what roles?
10. What roles did/do other actors play (grid companies/ renewable energy associations, users) in the development of solar and wind power in China?

#### Understanding niche accelerations and barriers

11. To what extent do you think the development of wind and solar power has challenged the development of fossil fuels in China at national level and at two regions?
12. What do you think are the challenges for the further wind and solar power development in China?
13. What do you think would be the future of renewable energy/ coal power/ grid system in China? And why?

#### Understanding the divergence of two regions

14. What are the reasons for lesser developed installed capacity of wind power in Jiangsu province in terms of wind power compared with Inner Mongolia?
15. Why Jiangsu province has a rapid deployment of solar PV?
16. Why Inner Mongolia and Jiangsu province take up divergent solar PV development pattern? What are the main factors? Who are the main actors get involved? How do these actors shape this development? How do these actors interact with national actors such as central government and investors?
17. What do you think will the future energy system look like for the two provinces (Inner Mongolia and Jiangsu)? Will it be more centralised with long transmission line or it would be more distributed? Why do you think so?

## Appendix C Supplementary data

Table C.1. China's renewable energy cumulative installation targets for 2020 from different planning regimes.

<b>2020 targets (installed capacity)</b>	<b>Medium and Long-term development plan for renewable energy</b>	<b>Energy Development Strategic Action (2014–2020)</b>	<b>Energy Development 13<sup>th</sup> FYP</b>	<b>Energy Production and Consumption Revolution Strategy (2016–2030)</b>	<b>2015 Levels</b>
Issuing organisation	NDRC, NEA (issued in 2007)	Office of the State Council (issued in 2014)	NDRC, NEA (Issued in 2016)	NDRC	
Wind	5GW by 2010, and 30 GW by 2020	200GW	210-250GW		129GW
Solar	0.3GW. <sup>15</sup> by 2010, 1.8GW by 2020.	100GW	110-150GW		43GW (43.18)
Biomass			15GW		
Hydro		350GW	340GW		320GW
Non-fossil fuel		More than 15% of primary energy consumption by 2020.	More than 15% of primary energy consumption by 2020	Non-fossil fuel in the energy mix should be higher than 20% by 2030; Non-fossil power generation account for more than 50% of total generation;	
Coal powers		Reduce the share of coal power in the electricity mix to lower than <b>62%</b> by 2020.	Reduce the share of coal power to less than <b>58%</b> by 2020.	Primary energy consumption of coal power should be capped below 6 billion tce;	

Table C.2. Coding structures of institutional work.

	<b>Forms of institutional work</b>	<b>Codes</b>
<b>Creating</b>	Advocacy	C1
	Defining	C2
	Vesting	C3
	Constructing identities	C4
	Changing normative associations	C5
	Constructing normative networks	C6
	Mimicry	C7
	Theorizing	C8
	Educating	C9

<sup>15</sup> It includes solar PV and solar thermal together.

<b>Maintaining</b>	Enabling work	M1
	Policing	M2
	Deterring	M3
	Valorising and demonizing	M4
	Mythologizing	M5
	Embedding and routinizing	M6
<b>Disrupting</b>	Disconnecting sanctions	D1
	Disassociating moral foundations	D2
	Undermining assumptions and beliefs	D3

Table C.3. Portfolios of institutional work adopted by actors shaping solar PV development at national and two provincial level.

	Forms of institutional work	National level	Inner Mongolia	Jiangsu
<b>Creating institutions</b>	Advocacy: The mobilisation of political and regulatory support through direct and deliberate techniques of social suasion	Solar PV associations lobby central government to support the industry development;	Provincial government and national solar PV industry association, local grid company, lobby central government to support large-scale centralised power plants deployed in the province.  In 2016- when the central government put stringent policy which cancel the construction of new coal power plants in Inner Mongolia, provincial government and thermal power companies lobby the central government to cancel the regulation of thermal power in the region.	Local solar PV industry association lobby provincial government to set up subsidy and other support for the local solar PV deployment.
	Defining The construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies within a field;	Not present	Not present	Not present
	Vesting The creation of rule structures that confer property rights	In 2007 the medium-long term renewable development plan- set up mandatory quota which requires the conventional utilities to install certain proportion of renewable energy in their	Provincial government set targets for solar PV deployment; provincial solar PV industry association set targets to encourage the integration of solar PV into grid to solve the high curtailment issues;)	Apart from setting up targets for solar PV deployment, the province set up the provincial level subsidy for solar PV deployment.

		capacity portfolio, also requires the grid company to purchase all the renewable energy generation.		
	Normative pillar Constructing identities (defining the relationship between an actor and the field in which an actor operates)	In 2010, central government denoted the solar PV industry as the strategic emerging industry.	Inner Mongolia -was constructed as the country's large clean energy sites which offers to supply clean energy to other provinces - this helps to re-define their relations between the other provinces.	Provincial grid company construct their new identities as the service supplier instead of energy products supplier in the envisioned future energy system;
	Changing normative associations (re-making the connections between sets of practices and the moral and cultural foundations of these practices)	Solar PV manufacturing and local governments reconnected the normative associations between the deployment of large-scale solar PV power plants with the desertification prevention.	Provincial government reconstructed the region as the national clean energy supplier- instead of just the large energy supplier- this fits the increasing environmental concerns and the legitimacy of the clean and low-carbon in the society. Regime actors, for example, the grid company and the provincial government advocating the national government to support the construction of UHV which could help the transmission of clean renewable energy from the province to other regions. Niche actors also construct the normative association of solar PV for clean and low-carbon development with the environmental concerns,	Local solar PV association changed the normative association of the distributed solar PV system from improving the green and low carbon energy system to also improve the grid resilience to respond to the fluctuating demand.

			and later on re-construct new value-solar PV for poverty alleviation.	
	Constructing normative networks (Constructing of interorganisational connections through which practices become normatively sanctioned and which form the relevant peer group with respect to compliance, monitoring and evaluation)  [for example, construct the new business model;]	National solar PV manufacturing industry constructed different business models to promote solar PV deployment, for example, solar PV + model- which refers to the solar PV together with agriculture/ fishing etc. business models	Provincial government encouraged direct trade of large generators with the large users, this construct new networks between generators and users, this undermines the conventional monopoly power of grid company, but also encourage the incentives for the power generators to build more economic efficient large scale centralised power plants.)	The province experimented peer to peer trading which is also based on the legitimacy that encourages the liberalisation-oriented electricity sector reform.  .....
	Cognitive Mimicry (Associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption)		Not present	Not present
	Theorising (The development and specification of abstract categories and the elaboration of chains of cause and effect)		Not present	Demonstrating the village with the installation of the distributed solar PV system as the national model for the ecological development, connect with the broad value of 'ecological civilisation' and 'beauty China'.
	Educating (The educating of actors in skills and		Not present	Local EPC (engineering, procurement and construction (EPC)) solar PV companies educate users what DSPV is to promote

	knowledge necessary to support the new institution)			the local diffusion. These EPC companies together with local government and also the local grid company to manage the risks of grid connections with distributed solar PV system through doing experimentations.
<b>Maintaining institutions</b>	Enabling work (The creation of rules that facilitate, supplement and support institutions, such as the creation of authorizing agents or diverting resources;)	The grid company introduced the grid connection standards for solar PV integration.	Local provincial government encourages capacity market and auxiliary service for thermal power to further enforce the centralised power system. This enables the coal power plants get motivation to provide the auxiliary service for renewable energy. This also build the new moral connections between thermal power plants and renewable energy- that thermal power can provide auxiliary service for renewable energy to keep grid stability.	Not present
	Policing (ensuring compliance through enforcement, auditing and monitoring)		Both the central government and the local solar PV industry association set up the targets-oriented policy to guarantee the renewable energy integration.	Not present
	Deterring (Establishing coercive barriers to institutional change)		Not present	Not present
	Valorising and demonizing (Providing for public consumption positive and		The provincial grid company demonised the integration of solar	Not present



	negative examples that illustrate the normative foundations of an institution)		PV into the grid which will cause less stability problems. The coal power regime actors valorised the benefits of coal power plants which is clean with technology improvement and can attribute to the safety and stability of electricity system and also the local employment.	
	Mythologizing (Preserving the normative underpinnings of an institution by creating and sustaining myths regarding its history)		Not present	Not present
	Embedding and routinizing (Actively infusing the normative foundations of an institution into the participants day to day routines and organizational practice)		Not present	Not present
<b>Disrupting institutions</b>	Regulative pillar Disconnecting sanctions (Working through state apparatus to disconnect rewards and sanctions from some set of practices, technologies or rules)	Central government capped the coal power capacity by 2020; Central government implemented the policy to gradually cancel the annual generation quote of thermal power.	Not present	Provincial government implemented such as the 263 policy to cap the coal power plants in 2020.
	Disassociating moral foundations	Disassociating the dominate position of coal power in the	Not present	The local solar PV investors disassociated moral foundation of coal power plants for the stability of grid- while encouraged the

	(Disassociating the practice, rule or technology from its moral foundation as appropriate within a specific cultural context)	future energy system with the environmental concern;  Central government reform the electricity market- based on the legitimacy of introducing the competition in the retailing market. – this undermines the monopoly power of the grid company;		integration of clean and low-carbon energy towards more local energy efficient and environment friendly distributed energy system.
	Undermining assumptions and beliefs (Decreasing the perceived risks of innovation and differentiation by undermining core assumptions and beliefs)		Not present	Provincial solar PV association and local solar PV investors encouraged deployment of more distributed energy system and undermined the assumption and beliefs of the economic efficiency of large-scale long-distance transmission line.

Legend: Light background blue colour corresponds to the regulative pillar;

Light background orange colour corresponds to the normative pillar;

Light background pink colour corresponds to the cognitive pillar.