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Niche acceleration driven by expectation dynamics among niche and regime actors: China's wind and solar power development

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Abstract

This paper addresses the question how does the alignment of expectations between niche and regime actors unfold during niche development process, and how it shapes the niche development process? In this paper we offer a theoretical framework with three alignment patterns: strong, medium-strong and weak alignment, based on niche and regime actors' expectation structures. The research aims to establish whether the alignment patterns match three distinct stages of niche development: slow niche development; moderate niche development and substantial niche acceleration. We propose a 16% threshold in terms of adoption for niche acceleration. We apply the conceptual framework to two long-term cases, of wind and solar power development in China between 2000 and 2017. These present two independent cases with different stages of niche development during the studied period, but in the end both show niche acceleration. Our two cases suggest that although alignment patterns between both cases differ, they match niche development phases. Strong alignment does go hand in hand with niche acceleration. Overall, this paper contributes to both a conceptual and methodological understanding of how the alignment patterns between niche and regime actors' expectations contribute to niche acceleration.

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

Highlights:

- Investigates how the alignment between niche and regime actors unfolds for sustainability transition.
- Conceptualises three alignment patterns between niche and regime actors' expectations.
- Matches expectation alignment patterns between niche and regime actors with niche development phases
- Traces alignment dynamics between niche and regime actors' expectations for wind and solar power development in China from 2000 to 2017.
- Concludes strong alignment between niche and regime actors can accelerate niche development.

Abbreviations

GWEC-Global Wind Energy Council
S&T-Science and Technology
CWEA-Chinese Wind Energy Association
IEA-International Energy Agency
NEA-National Energy Administration

[1] This manuscript has been submitted to the Environmental Innovation and Societal Transitions journal.

CEC-China Electricity Council
RE- Renewable energy
MLP- Multi-level perspective
SNM-Strategic niche management
TIS-Technological innovation system

1. Introduction

This paper addresses the question how does the alignment of expectations between niche and regime actors unfold during a sustainability transition process, in particular how it shapes 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., 2012; Späth et al., 2016). As pointed out by Geels et al. (2012), "while pioneers, entrepreneurs and start-ups were important for the early development of FCVs (Fuel Cell Vehicles) and BEVs (Battery Electric Vehicles), the upswing and acceleration of niche-innovations probably depends on the involvement of regime actors" (p369). Niche actors need political power, finances 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, regime actors are often locked into their routines and will not strategically contribute to the acceleration of niche development since this may hurt their main business (Jacobsson and Bergek, 2004; Smink, 2010; Smink et al., 2015). Thus strategic collaborations between the two with the aim of niche acceleration are unlikely to happen until regime actors start to question the regime resilience, i.e. the ability to cope with immediate challenges through optimizing the regime (Geels, 2010; Turnheim and Geels, 2013).

Strategic collaboration between niche and regime actors can cover many aspects (Rothaermel, 2001b; Stenzel and Frenzel, 2008; Elzen et al., 2012; 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 such a strategic collaboration between niche and regime actors. The crucial role of expectations for forging collective actions among actors is widely recognised in the sociology of expectations literature as well as in the sustainability transitions literature (Brown et al., 2003; Berkhout, 2006; Konrad, 2006; Schot and Geels, 2008; Budde et al., 2012; Budde, 2015). The reason for this strategic role is that expectations can generate ex-ante selection pressures. They define a future selection-environment in which the actors need to operate. If actors assess they are not fully equipped to act in that future, they may invest in new directions (niches) despite the fact that 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 into the niche development based on their expectations and beliefs 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 it could be a key way of niche actors to expand their social network and to build internal momentum for niche acceleration (Schot, 1998; Schot and Geels, 2008).

What we offer based on our literature review is a theoretical framework. The framework helps trace potential types of alignment between niche and regime actors' expectations, and matches these types to niche development phases. We conceptualise three basic types of alignment patterns: weak alignment, medium-strong alignment and strong alignment, and three niche development phases:

slow niche development, moderate niche development and substantial niche acceleration. We bolster the robustness of the framework with two longitudinal case-studies of wind and solar power development in China from 2000 to 2017. This allows for a systematic comparison. We use the case studies for theoretical generalization or sampling (George and Bennett, 2004; Eisenhardt and Graebner, 2007; Yin, 2013). This implies that we use the empirical analysis to sharpen our ideas and develop the framework. Both cases are suitable for developing the framework because wind and solar power have taken off rapidly but not at the same time, while twenty years ago, both were virtually non-existent in the country (see Fig. 1). We can thus observe niche acceleration in different time periods within the same context (China) and explore whether we can relate these contrasting periods within each case-study 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 type of actors may have a particular relationship due to the specific role of the state in China. This issue will be discussed in the final part of the paper.

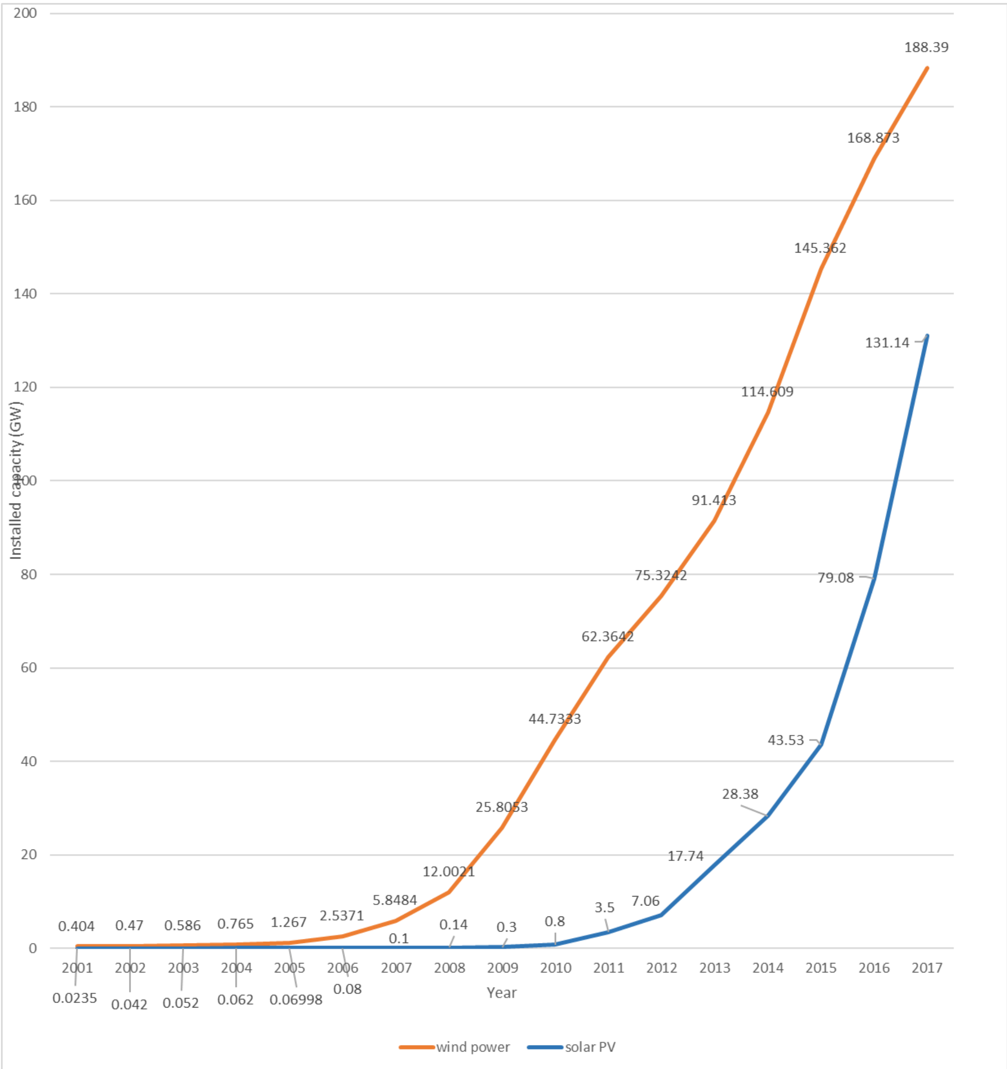


Fig. 1 Historical development of installed capacity of wind and solar power in China from 2000 to 2017.

Source: wind power data from the Chinese Wind Industry Association (CWEA) [2] and Wang et al. (2012); solar power capacity from statistical data provided by International Energy Agency (IEA).

The paper is structured as follows. Section 2 introduces the concepts of expectations and alignment building on 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 operationalization and methodology. Some of the key aspects of the framework need contextualisation. For example, to specify who are niche and regime actors and which phases of niche acceleration we have in two cases to apply our conceptual framework. Finally, we present how we have 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 on the discussion.

2. Aligning expectations in sustainability transitions

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 and images of the future (Garud and Ahlstrom, 1997; Rip and Talma, 1998; Van Lente and Bakker, 2010). This is especially true for the niche (new entrants) and regime (incumbent) actors. When expectations become shared or aligned across niche and regime actors 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. In other words, expectations about possible developments create windows of opportunity for actors to work on socio-technical system change, before it has happened. They guide actors' activities towards necessary actions for seizing opportunities (Van Lente and Rip, 1998).

Konrad (2006) argues in a similar way that widely shared expectations become a social repertoire for a specific community and public in general. Such a repertoire holds forcing power 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. Van Lente and Rip (1998) further articulate that actors actively coordinate their actions in a process of building a shared expectation about the future, while this future simultaneously is shaping the emerging socio-technical system.

How do we know whether expectations are shared or aligned? Based on the Strategic Niche Management (SNM) literature we suggest two dimensions to measure alignment between niche and regime actors (Schot and Geels, 2008). First, the *broadness* of alignment, i.e. how many niche and

[2] Note: the data provided by CWEA is different from the one provided by the NEA. The data provided by NEA is the grid-connected installed capacity, while the data provided by CWEA refers to the wind turbine that has been installed may not necessarily connected to the grids. Thus generally, the data provided by CWEA is higher than the data provided by NEA.

regime actors are aligned. When expectations are more widely shared, it is more likely they are translated into actors' shared goals and collective activities. Second, the *depth* of alignment, this relates to what is called in the SNM literature the quality and specificity of the shared expectations (Schot and Geels, 2008). We will operationalize this dimension by mobilising a Multi-Level Perspective (MLP) understanding of expectation structures, building upon the work of Truffer et al. (2008) and other scholars in sociological studies of expectations and sustainability transitions literature.

In the seminal work by Van Lente (1993), he already made a distinction of three different levels of expectations: micro, meso and macro-level. For him micro-level expectations refer to the specification for the artefacts, systems or process to be developed. They function as heuristics and guide the search processes. The meso-level expectations are less specific. They tend to express functions that the technology presumably will fulfil. The macro-level expectations are broad and general. They have the form of scenarios about the technology as a whole to fit societal trends, which provide the legitimacy for the 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 expectation at the three levels follow different hype-disappointment patterns. This implies that actors may hold different natures (positive or negative) of expectations at the three levels. Budde et al. (2012) prove this point in their case study of Germany's mobility system. Although showed positive expectations about the hydrogen and fuel cell niche technologies, the German government anticipated less positive landscape level development. This led its reduction in investment in these niche technologies. This case illustrates that it is crucial to measure the nature of actors' expectations across different levels so as to understand actors' strategies. Kriechbaum et al. (2018) further 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 they neglect the expectations about regime resilience. Inspired by MLP, Truffer et al. (2008) suggest actors' expectation structures for the system transformation could be mapped in accordance with MLP levels: niche, regime and landscape. They argue actors' strategies and activities are not only influenced by their expectations about emergences 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 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, but also include the policy actors' expectation dynamics. They prove that policy should also responds to the changing expectation dynamics at three levels. Building on these findings of the literature we can construct a theoretical framework for alignment dynamics between niche and regime actors' expectations that includes a notion of broadness as well as depth of alignment.

2.2 Typology of alignment dynamics between niche and regime actors' expectations

Alignment is not a 0/1 dichotomy, in reality there will be a wide spectrum between no alignment and complete alignment, and actors may change position over time. 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). Regime actors are heterogeneous and hold different resources and capabilities. When confronted with pressure or crisis, they perceive different opportunities and may perceive different natures of expectations of niche and landscape development (Smith, 2007). Similarly, niche actors may have different expectations about options for niche development and the obduracy of the prevailing regime and landscape developments.

To measure the dynamic process of alignment between niche and regime actors, we develop in this section a theoretical framework that contains a typology of alignment patterns. All building blocks are based on existing literature. Our contribution is the specific way we put them together. The expectation alignment dynamics typology framework is built 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 broadness of alignment between niche and regime actors at each separate level. In Step 3 we systematically combine steps 1 (depth of alignment) and 2 (broadness 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 at three different levels

Following Truffer et al. (2008), Budde and Konrad (2019) we distinguish between three levels of expectations by both niche and regime actors[3]:

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

Regime-level expectations: this is the expectation of regime's resilience to adapt to internal tensions and crises or to external pressures. If the expectation becomes negative, it will lead to regime destabilisation. Regime resilience covers all dimensions of the dominant socio-technical system. For

[3] Our definition is different from Truffer, Voß et al. (2008). Their definition of the collective expectation at the niche level specifically focus on the sectoral or national priorities in innovation policy to support promising technologies. We expand their scope to the expectations related to the emerging socio-technical structures, which include policy, industry, market, technology performance, and user behaviours etc. Our interpretation of the three levels is also different from that of Budde and Konrad (2019). For example, they interpret the expectation of the fossil fuel price as the landscape level, here we would like to argue that is the regime level expectation– which covers different elements of the dominated socio-technical system (including the industry dimension- the supply and demand side, see our Table 1 for specification). They defined the proportion of the RE in the system as the regime level expectations but in our paper we define that as niche level expectation. See their definition of three levels expectations on p. 1101.

example, for our case study it includes technology performance of thermal power, its policy support and the market environment etc.

Niche-level expectations: this concerns expectations of future performance of the specific socio-technical configurations of emerging technologies, such as the role of wind power in meeting energy demand, the technology performance or expected market competitive advantages. When positive, they will contribute to niche acceleration. The 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 broadness of alignment between niche and regime 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, the broadness of alignment is defined by three types of alignment (in terms of how broad they are) between niche and regime actors: 1) *low broad*, which refers to a spectrum closest to no regime actors align with niche actors; 2) *high broad* applies to a spectrum closest to all of the regime actors aligning with niche actors; 3) *semi-broad*, when only a few regime actors align with niche actors. The latter is an intermediate status between low broad and high broad alignment. We thus propose to measure the three degrees of broadness by counting how many regime actors align with niche actors in terms of their expectations at a specific level.

To measure and define semi-broad alignment we need to know what counts as a few actors, and this depends on the context and structure of the socio-technical system under study. Therefore, 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 for our case study below.

We are now in the position to define broadness of alignment between niche and regime actors' expectations in terms of each of the three levels. This is also recognized in the literature, albeit not in a systematic way. Broadness at each level can be described as:

1) *Broadness of alignment between niche and regime actors' expectations at landscape level*

When regime actors begin to share the perception that changes at the landscape level challenge the future regime resilience, more pressure is generated to open up 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 at 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). For example, renewable energy could be labelled as promising solutions to social or environmental issues (climate change or air pollution), and to create cultural and political legitimacy for the sector. When this happens regime actors may begin to consider investing seriously in renewable energy as a necessary step for a future clean and 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) *Broadness of alignment between niche and regime actors' expectations at regime level*

When alignment between niche and regime actors' expectations is low broad or weak at the regime level, it refers to a situation in which neither niche nor regime actors question the regime's incapability to respond the internal crises and/or external pressures, and hence regime destabilisation. In such a case niche actors may aim for niche development at a limited scale because niche 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 is not only at risk, but may fall apart because it cannot respond anymore to future threats and opportunities, it indicates that regime actors have started to question regime resilience towards external pressure and internal crisis. This also means that they are searching for alternative choices, which could open spaces for niche acceleration. This search process will have to become focused on specific paths of niche acceleration.

3) Broadness of alignment between niche and regime actors' expectations at niche level

The measurement of this level's expectations plays a crucial role and has been discussed mostly compared with the other two levels in the transition studies. Only when niche and regime actors share expectations about the viability of specific niche technology, regime actors will 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 step 1 and step 2. Now we have finished the assessment of actors' expectations at three separate levels (step 1) and the assessment of three different degrees of broadness at each level (from high broad, semi-broad to low broad). Theoretically, we are able to distinguish 27 (3*3*3) different types of alignment combinations between niche and regime actors' expectations during the transition process. These are presented in Fig. 2 below.

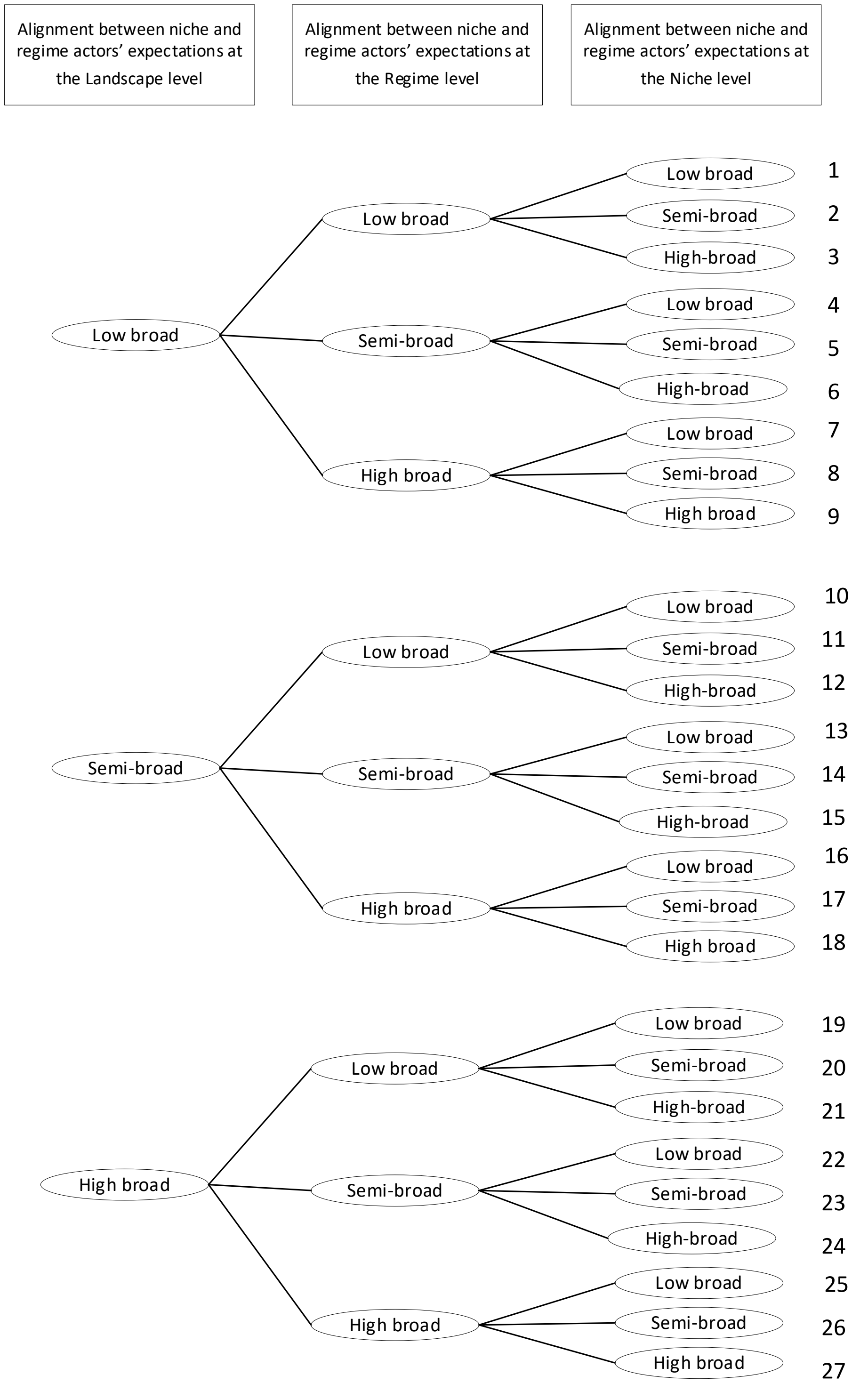


Fig. 2 Typology of 27 theoretically possible alignment dynamics between niche and regime actors' expectations

In reality, however, not all these options will be relevant for our research question that aim for understanding the connection of alignment between niche and regime actors to niche acceleration. With help of the sustainability transitions literature we can reduce the 27 to 12 possible types by taking into account the following considerations. First, we can exclude the low alignment between niche and regime actors' expectations at all three levels (type I, in Fig.2) as this type does not contribute to niche acceleration. Second, landscape level expectations are more general compared to 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 the following alignment patterns: types 2, 3, 4, 5, 6, 7, 8, 9, 16, 17 and 18 (depicted in Fig.2) where niche and regime actors share broader alignment at niche and regime level compared to the alignment at the landscape level. These are dismissed as unrealistic scenarios. Third, the 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 reasons, 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 strategic importance of specific niches, not just for the sake of new opportunities, but 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 share high broad alignment at niche level (i.e. all niche and regime actors share expectations of niche development) while holding semi-broad alignment at the landscape and regime level.

For the remaining twelve types of alignment (Fig. 3), based on the proposed two dimensions (broadness and depth of alignment), we can distinguish three different basic alignment patterns:

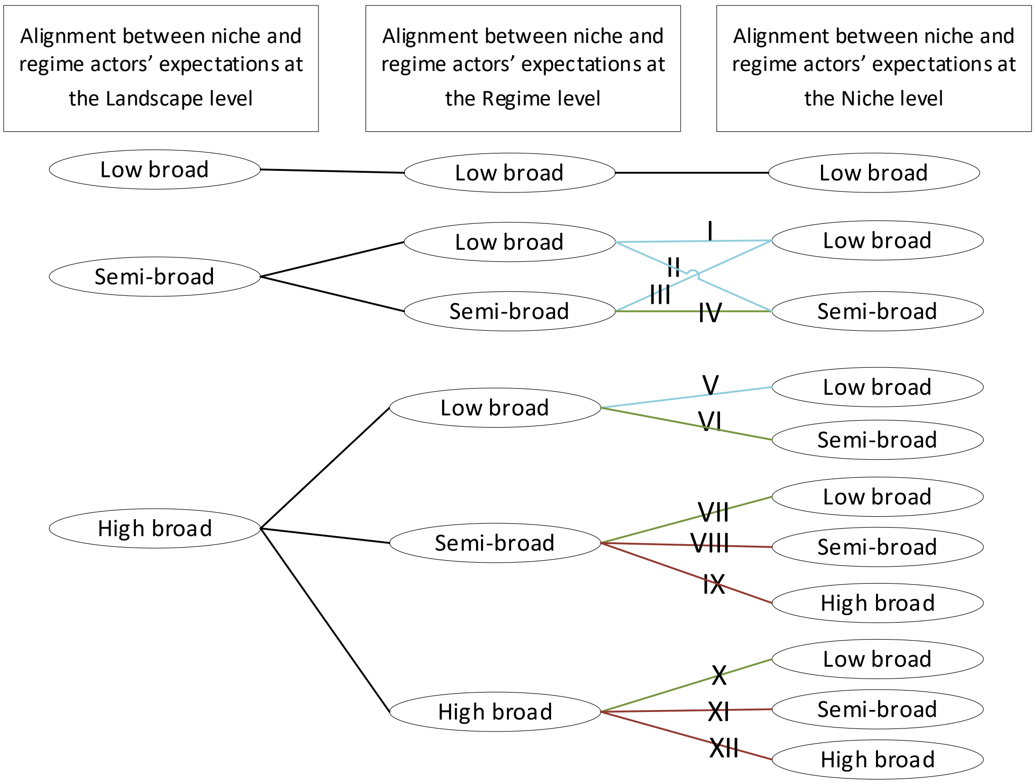
Weak alignment refers to a situation in which niche and regime actors do not have a high broad alignment at the landscape level (but only a semi-broad alignment) and a variety of alignments at the two other levels, but never a high broad alignment or a semi-broad alignment at the two other levels (types I- III); or a situation when there is high broad alignment at the landscape level but this has not resulted (yet) at a semi-broad level of 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, V, niche and regime actors share limited expectations of both niche and regime's development. Regime actors are deeply embedded into their routines, and belief optimisation is a viable way to go. They generally do not share expectations with niche actors or they do not recognise niches as a threat to the regime future. Moreover, at the early stage of niche development, niche actors may focus on the niche and have no clear visions on how the process of regime destabilisation may happen. Niche actors hold limited social networks, these are less stable and the niche technology improves within the protected space where it is isolated from the dominant selection environment. Niches may expand if there is leeway from 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 a very limited niche development, especially when there is insufficient pressure at the landscape level. Alignment type III emerges when regime actors start to question the regime's resilience and expect that the regime may 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 the other competing alternatives, such as hydropower and nuclear power. Therefore, the limited alignment of expectations of 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 come to semi-broad alignment at all three levels, but not high-broad alignment (type IV); or have high-broad alignment at landscape level, and semi-broad alignment at niche level, but regime actors still hold on to the resilience of the dominant regime resulting in a low-broad alignment at this level (type VI); or have high alignment of expectations at the landscape level which has resulted in semi-broad or even high-broad alignment about regime-resilience but not yet any alignment about specific niche acceleration (types VII, X). In all 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 of a niche technology. Niche actors also begin to envision the future regime they aim to build, which provides an alternative future for the dominant socio-technical system. This imagination, for example, the RE penetration scenario 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 condition for niche acceleration. However, the limited questioning of the regime resilience and the consequences of landscape pressures may restrict the large scale investment in niche development (Schot and Geels, 2007; Turnheim and Geels, 2012; Turnheim and Geels, 2013). But even when regime actors begin to question the regime resilience and are starting a "more distant search and exploration of technical alternatives" (Turnheim and Geels, 2013) (p1754), they may invest in multiple niches leaving limited resources for specific ones (as for the alignment types VII and X).

Strong alignment refers to alignment types VIII, IX, XI and XII (in Fig. 3), which have high broad alignment at landscape level and at least, semi-broad 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*" (p430). When the regime actors and niche actors align their understandings of landscape developments, it provides a window of opportunity for niche actors to mobilise the landscape pressure as resource for articulating concrete regime pressures (for example, the perception of climate change exerts strong pressure of the fossil-fuel dominant regime towards renewable energy). Moreover strong alignment between niche and regime actors' expectations at the regime level indicates regime destabilisation, which contributes to the further breakthrough of niches (a hypothesis developed by Schot and Geels (2007) and supported by Turnheim and Geels (2012)).



Weak alignment: I, II, III, V ; Medium-strong alignment: IV, VI, VII, X ; Strong alignment: VIII, IX, XI, XII

Fig. 3 Different alignment patterns between niche and regime actors' expectations.

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 be gaining some momentum during the medium-strong alignment phase. This specification still begs the question how we establish whether niche acceleration has happened? Niche acceleration is not just about adoption of 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 the historical analysis of the development of the automobile regime (Kanger and Schot, 2016).

But how do we know whether such an 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 in fact, diffusion curves are often used in sustainability transition studies (Rotmans et al., 2001; Elzen et al., 2012; De Haan et al., 2016; Kanger and Schot, 2016).

Rogers (2010) distinguished five different 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 Fig. 4). Early adopters are visionaries, they want what others do not have and are happy to promote a discontinuity between old ways and the new, and are prepared to champion this cause 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 the 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 may 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 beyond 16% we assume a substantial niche acceleration (moving into group of early majority).

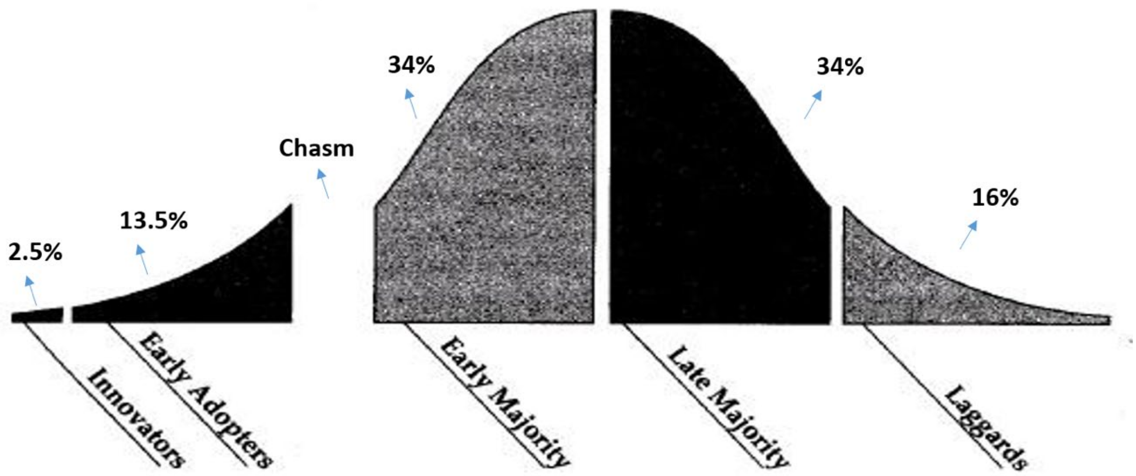


Fig. 4 Revised technology adoption life cycle.
adapted from Moore (1991) and Rogers (2010)

3. Methodology

3.1 Specifying our framework for our case-study: niche acceleration

Diffusion studies express the market share of new technologies in terms of number of adopters, however, we think the 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 yearly new installed capacity for wind and solar, and included the figures of other niches and installed capacity of coal power plans (see Fig. 5). In our case we could also have taken the increasing rate of electricity generation or cumulative installed capacity but data are lacking.

When we apply these thresholds to our two cases we get the following picture. For the wind power we can distinguish three stages of development: Stage 1: 2000-2007, slow niche development; Stage 2: 2008-2010, moderate niche development; Stage 3: 2011-2017, substantial niche acceleration. Solar power development can also 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.

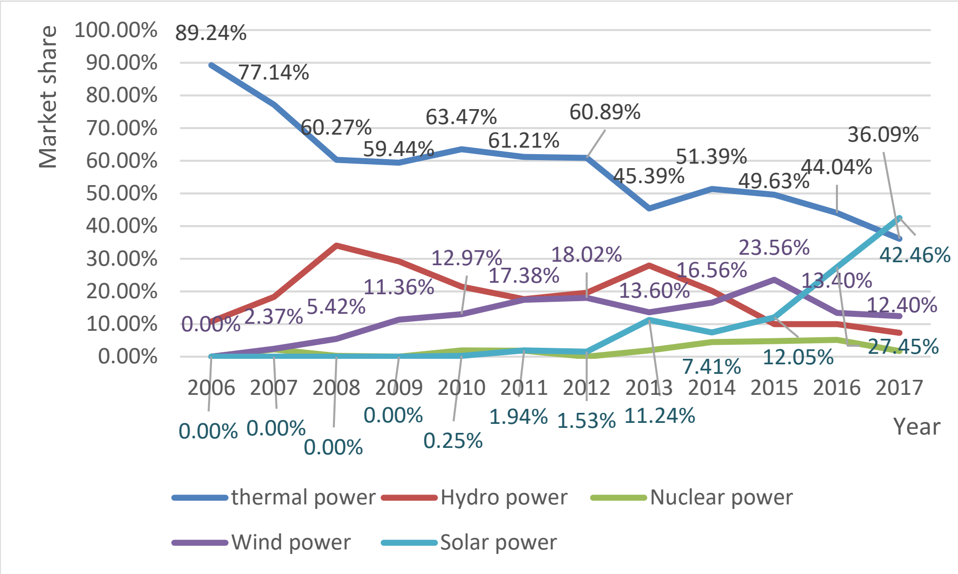


Fig. 5 Different electric powers' market share of newly installed capacity per year: 2006-2017. source from CEC- calculated by the author

3.2 Specifying niche and regime actors

Our framework focuses on alignment among 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 and 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) which are in charge of transmission and distribution across China (apart from the western part of Inner Mongolia); 'Big Five' power generators and other four 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: the 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 organizations (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 the large industrial users started to play a role at a later stage of development.

To define the semi-strong alignment pattern, the threshold that we used in our two cases strongly depends on the shifting of key actors' expectation dynamics. In our two cases, the key regime actors are the central government, coal power generators, and the grid company; and the key niche actors are wind and solar power generators and the manufacturing industry (as depicted in Fig. 6). For example, when either two of the three key regime actors share expectations with the niche actors, then we categorise them as the semi-broad alignment at the niche level. Low-broad alignment at the niche level refers to less than two of the key regime actors (central government, state grid, coal power generators) align with the key niche actors (manufacturing industry and wind and solar power generators). Semi-broad alignment at regime level refers to one of the two key niche actors sharing expectations with regime actors. Low-broad alignment at the regime level refers to none of the key niche actors sharing expectations with regime actors. High-broad alignment at niche/ regime level refers to all of the key regime actors aligning with the key niche actors' expectations.

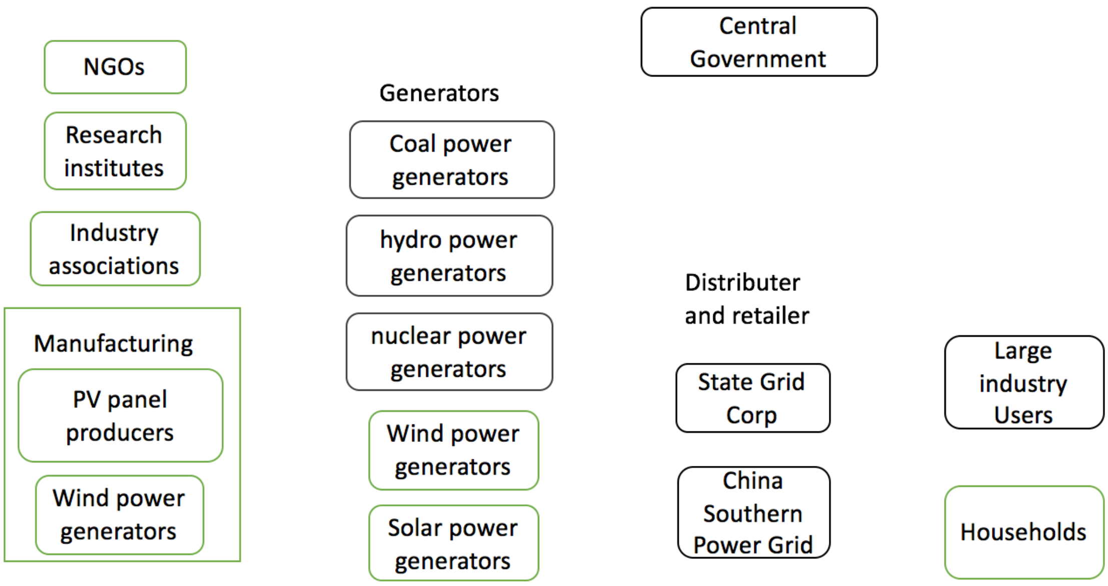


Fig. 6 Key stakeholders in China's electricity sector.
Legend: Rectangle with black line refers to regime actors; Rectangle with green line refers to niche actors

3.3 Data collection and analysis

3.3.1. Data collection

Data collection included: i) thirty-one semi-structured and six informal interviews with relevant actors; ii) a workshop[4] with twenty-two participants representing both niche and regime actors; and iii) desk-based research, in particular retrieval of news items from relevant websites, professional journals and reports of various organisations.

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

To overcome the above challenges, multiple experts from similar groups were interviewed to reveal expectations and limit the individual bias (Eisenhardt and Graebner, 2007). For example, the study included four interviewees from central government so that they could validate each other (see Table A1 in the Appendix). 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 crucially important to identify alignment patterns among actors. If actors expressed different expectations or expectation alignment was not clear, additional data was sought through archival data sources.

The interview questions were constructed by first author and discussed and agreed among three authors. For constructing interview questions, we used a list of items presented in Table 1. These were not distributed beforehand, only when requested. We asked interviewees questions not just related to their own expectations, but also questions about expectations of other actors for triangulation purposes. In order to allow the interviewees to speak relatively open, they were guaranteed confidentiality. All of the semi-structured interviews were audiotaped and each interview lasts for around one hour. Apart from one interview was conducted in English, the rest thirty were conducted in Mandarin. After each interview, the first author produced the English interview summary report and the three authors discussed results on a regular basis, which also led to adjustments in interview strategy. Meanwhile, all of the thirty-one semi-structured interviews were transcribed and thirty of them were translated from Mandarin to English. The six informal interviews were conducted at a later stage of the fieldwork, in 2018 from January to February. They were conducted in an un-structured way, and done in an open and relaxing environment, for example over a meal. They were used to discuss sensitive issues such as expectations from coal and grid companies and solve inconsistencies. They were not recorded and the first author only produced an English summary.

The workshop took place in March 2018 with all authors present. The aim was to discuss the historical development (selection of key events) of wind and solar power development from 2000 until 2017, agree on niche development phases and on the relationship among main actors during the development process, in a setting which was invited to discuss opinions and build consensus. First author provided input to the workshop by producing case-study reports on both wind and solar based on summary reports of thirty-one interviews and archival data. During the workshop, we collected

[4] 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).

data using different formats, invited lectures, plenary discussions, and facilitated group discussions. Specifically, we conducted two focus group discussions on wind and solar power. A workshop report was produced afterwards.

The archival data included: news articles from China's largest professional electric power news website[5], 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 until 2017, and reports produced by the State Grid from 2015 to 2017; professional journal articles, including China's professional journals on RE energy, <Solar Energy>, <Wind Power>, <State Grid> (searched using keywords "solar power", "wind power", "thermal power/ coal power", "electricity", "renewable energy"); 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>, etc.

3.3.2. Data analysis

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: S&T, Political, Industry, Market and Culture. Our analysis started with coding using keywords from Table 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 1 Expectation's content at the landscape, regime and niche level in five dimensions of socio-technical system.

	Landscape level	Regime level	Niche level
S&T	The future political, economic, environmental and societal development	The future innovation capability of regime technology in adapting to external pressure	Specific project/product/organisational future performance; The expectation of future technological performance (technology advance rate; stability; perceived uncertainty (Meijer et al., 2007); competitions between other technologies;)
Political		Policy and government support; laws; regulations; guidelines; standards	Stable long-term regulations, laws, supporting policies, political commitments, political legitimacies
Industry		Industry capability, organisational capability, complementary assets (for example infrastructures); financial capability	Manufacturing capability; the price and supply of materials and other resources; the accessibility of complementary assets, such as infrastructure and other resources (material, human and financial resources availability)
Market		Market supply; market structures; users' preferences; market rules	The expectation of future market/ profitability; for example, whether renewable energy has a future in the energy mix? And how large would that be? How fast it will increase?
Culture		Social acceptance of regime technology; changing value priorities (economic efficiency, environmentally friendly,	The social meanings and social functions of the niche technology. For example, the role of renewable energy in dealing with energy security, environmental issues or climate change

[5] All news titles from 2000 to 2007 were downloaded to identify the key relevant information, while the search used keywords "solar power", "wind power", "thermal power/ coal power", "electricity", "renewable energy" to get the archive from 2008 onwards because of the increasingly amount of yearly news which makes it almost impossible to read all the news titles after 2007.

		safety priority, or low-carbon preference, etc.)	

Coding led to two set of results: self-evaluated results and other stakeholder' evaluated results. This made it possible to cross-check these two sets of results, and see whether they are aligned with each other. If they aligned with each other we put the results (positive/ negative/ null) into the data result table (see Table 2 and 3). If they diverged we looked at our secondary data to come to 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 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. Also, for secondary data we constructed a database of relevant articles which we then coded.

The results we came up with are a result of a disciplined coding process coupled with triangulation of various sources and interpretation in order to come up with the final result. The first author was responsible for the coding and presenting a first interpretation which was then discussed with the other authors. An important interpretation problem was that we looked at expectation dynamics across different dimension of the energy system, from expectations about future S&T development to political developments and so on (see Table 1). This meant that a range of actors had to agree on expectations concerning each specific dimension. In case 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. They come in two forms: a table for wind and solar (Table 2 and 3) and a narrative. In the table we present three types of results for the nature of each niche and regime actor's expectation: "√"as "positive"; "×" as "negative"; "−" as "no information". In the table, we also show how actors' expectation dynamics at three levels match the niche acceleration stages we have identified beforehand, and converge with a specific alignment pattern.

4. China's wind and solar power development

4.1 Alignment dynamics between niche and regime actors' expectations of wind power

As indicated in Table 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, as shown in Table 2, for whom there is no sufficient information of their expectations. However, they don't influence the threshold of alignment patterns between niche and regime actors' expectations as their expectations won't strongly influence the other actors' expectations or they didn't explicitly concern 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 compared to wind power generators, instead the wind turbine manufacturers' expectations are more closely connected with the potential future of the market at the niche level.

Table 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 company	√	×	×	√	×	×→√	√	×→√	√
	Grid company	–	×	×	√	×	×	√	×→√	×→√
	S&T research institutes	–	×	×	–	×	–	√	–	–
	Electric power association	√	√	–→√	√	√	√	√	√	√
	Central government	√	√	–→√	√	√	√	√	√	√
	Large industrial users							√	√	×→√
	Financing agency	–	×	×	–	×	×	–	×→√	√
Niche actors	Wind turbine suppliers	–	–	√	√	×	√	√	√	√
	Wind power generators	–	–	–	√	–	–	√	√	√
	Component suppliers	–	–	√	–	–	√	√	√	√
	S&T research institutes	–	×	√	–	–	√	√	–→√	√
	Wind power association				√	√	√	√	√	√
	NGOs	√	√	√	√	√	√	√	√	√
Alignment patterns between niche and regime actors' expectations		Semi-broad	Low broad	Low broad	High broad	Low broad	Semi-broad	High-broad	Semi-→High broad	High-broad
		Alignment pattern 'I'; Weak alignment;			**Alignment pattern 'VI'; Medium-strong alignment;**			**Alignment pattern 'XII'; Strong-alignment;**		

Legend: " √ "as "positive" expectation; "×" as "negative" expectation; "–" as "no information; "→" indicates changes occur. Shadowed areas depict actors who haven't played a significant role at that specific stage.

Stage 1: 2000 to 2007 Weak alignment

From 2000 to 2007, there was weak alignment between niche and regime actors' expectations (belonging to pattern 'I' in Fig. 3 with semi-broad alignment at the landscape level, and low broad alignment at both regime and niche levels). Although at this stage, there are 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, however, we see less articulation of the landscape pressures from the niche actors.

Generally, at this stage, renewable energy took place at 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 the wind power development, but less priority was given compared to hydro and nuclear power. Wind power hasn't attracted significant attention from other industry regime actors, in particular from power generators and the grid company.

There was a widespread sharing of expectations among different actors of the short-supply issues of China's electricity system which would be accelerated with the continuously fast electricity demand to fuel economic growth. Pessimistic views about the levels of domestic coal reserves in China, which could fulfil the demand for twenty years at the most were widely spread in the public news (BJXnews, 2005). This leads to the large investment into hydro power construction instead of wind power construction (BloombergNEF, 2018). Narratives criticising the unsustainable 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 to 2010 Medium-strong alignment

There is medium-strong alignment between niche and regime actors' expectations at this stage (represented by pattern 'VI' in Fig. 3, with high broad alignment at the landscape level, low broad alignment at regime level, and semi-broad alignment at niche level). Actors' alignment at the niche level was broader compared to 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 an increased enthusiasm and commitment to wind power, which was endorsed as the most potential and advantageous renewable energy (Li et al., 2008; Han et al., 2009). In 2009, the central government set 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' of social investment, with an increasing number of wind power manufacturers. The central government introduced a renewable energy portfolio 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 coal power regime market. Furthermore, from 2008 onwards, with the decreasing of wind power plants cost and the belief of long-term positive government support for wind power, power generators started strategically setting 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 will be substituted by RE (Iizuka, 2015). Moreover, wind power was regarded as "rubbish electricity" by the grid company, which stated that the intermittency of wind power, its large 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 (i.e., reduction in electricity generation below what a system of well-functioning) at a later stage (Zhao et al., 2012).

Stage 3: 2011 to 2017 Strong alignment

There was a broader alignment between niche and regime actors' expectations at three levels compared with the other two stages (represented in pattern 'XII'). Actors' perceptions of pressure from the landscape level became clearer compared to former stages. Expectations were that the future of the energy system should be 'clean, low-carbon, safe and efficient' (National 13th Five-Year Plan for Energy Development, 2016). There is 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, endorsed by the <Energy Production and Consumption Revolution Strategy (2016-2030)> issued by NDRC and NEA, in 2017. This policy document recalls the targets set by the non-fossil fuel in the energy mix higher than 15% by 2020. It sets new targets for 2030 of achieving above 20% (see Table A2 in the Appendix). 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 the low-carbon strategy (Shi, 2014).

Government and industry actors regard 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; NEA, 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 towards external pressures. As indicated in the news: "*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 of wind installed capacity, the grid company improved their infrastructure capabilities and dispatch practices to integrate more renewable energy. The State Grid Corporation of China issued white paper <Promote the Renewable Energy Development> every year since 2015. Clean and low carbon have been integrated as values of its business strategies.

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 over time between 2000 and 2017 (see Table 3). The strong alignment between niche and regime actors' expectations at the niche level formalised almost at the same time at the regime level, which is distinguished from that of wind power. In the case of the latter, the build-up of broad alignment at the niche level took place before it achieves the same broadness of alignment at regime level. We present here the storyline of actors' expectations of solar power development, drawing attention mostly on the evolution of expectations at the niche level as the regime actors' expectations of the other two levels (regime and landscape) has been largely presented in the wind power case. However, we will present how the niche actors perceive the future of the landscape level and regime level development.

Table 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 company	√	×	×	√	×→√	×	√	√	×→√
	Grid company	–→√	×	×	√	×	×	√	×→√	×→√
	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 regime actors' expectations		Semi-broad	Low broad	Low broad	High broad	Semi-broad	Low-broad	High broad	High broad	High-broad
		Alignment pattern 'I'; Weak alignment;			**Alignment pattern 'VII'; Medium-Strong alignment**			**Alignment pattern 'XII'; Strong alignment**		

Legend: " √ "as "positive" expectation; "×" as "negative" expectation; "–" as "no information; "→" indicates changes occur.

Stage 1: 2000 to 2012 Weak alignment

There is a weak alignment between niche and regime actors' expectations of solar PV, representative of pattern "I", semi-broad alignment at the landscape level, low broad 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 will be a potential substitute of 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 largely deployed in the country. It was expected that solar PV won't be competitive in the market compared with the conventional power in the short term. As put by a central government expert: "*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 policy maker, Beijing, 12th Dec 2017). The domestic deployment of solar PV was predominately targeted at remote areas without electricity access, for example, in the western part of China. As stand-alone energy system, it was believed by the central government that solar PV is suitable for areas with limited access to electricity and weak grid infrastructure capability (NDRC, 2007), while too expensive to be largely used in the Chinese electricity market. Meanwhile, solar power was believed to be less competitive compared with other clean technology, such as hydro-power, nuclear power, wind and biomass (Li et al., 2007). According to the <medium-long term development plan for the RE (issued in 2007)>, the total capacity of solar power (solar PV and solar thermal together) targeted 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 for China in 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 will increase in the near future with the continuous reduction of solar panel costs. Especially after the then biggest manufacturing company, Suntech Power Holdings Co., Ltd., went public on the New York Stock Exchange in 2005, showing that solar PV can bring a large amount of wealth, the private enterprises started to influx into the solar PV manufacturing industry because of its bright future. This high expectation was further burgeoned when it was labelled as the strategic emerging industry by the central government in 2009. However, the high expectations towards the manufacturing industry didn't 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 are representative of pattern VII (see Fig. 3), which was medium-strong alignment (high broad alignment at landscape level, semi-broad alignment at regime level and low-broad alignment at niche level). With the increasing concern for climate change and the domestic air pollution problems, the thermal power regime started to be questioned by both niche and regime actors. However, the collective expectations between niche and regime actors were less strong compared to the later stage.

With the rapid decreasing of the solar panel costs, solar PV was perceived as a potential option for future clean energy deployment in China. Especially after the Fukushima nuclear accident in 2011, solar PV was articulated as one of the alternatives of clean and sustainable energy because of its safety advantages. Moreover, it was perceived that there will be limited potential to increase market for hydro power in China. Industry actors believed the solar PV industry sector to be a sunrise industry, which had great potential to fuel the future green economy. This expectation has been mobilised to lobby the central government to support the domestic market (Huang et al., 2016). Furthermore, solar PV was perceived to hold a potential large market with diversified applications, not just in terms of the centralised power plants but also the distributed solar PV panels. The flexibility of solar PV systems and the multiple emerging business models further credited expectations for fast increasing domestic market. The development of decentralised solar PV system was further expected to empower users and transform the whole energy system.

Stage 3: 2016 to 2017 Strong alignment

The alignment between niche and regime actors' expectations at the three levels are representative of pattern XII (see Fig. 3), which is strong alignment (high broad alignment at three levels).

Since 2016, the coal power regime started destabilising. The coal power was criticised as unsustainable, with negative impact on air quality and water consumption (Greenpeace, 2017). Along with the emerging oversupply issues in the electricity market, there were increasingly high expectations that coal power in China will peak in 2020 (Zhang, 2016). The central government showed determination to cap coal power plants. During a roundtable discussion of the transition of China's electricity system for the 13th Five-year Plan in January 2016, the experts agreed that the golden age of coal power has 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 the conference, for the first time, it officially declared the overcapacity problems of the coal power plants in China, and the development of thermal power entering into 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 is to provide a dispatch auxiliary service for renewable energy and to make space for renewable energy generation. In comparison, 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 one of the important strategies for big utilities, the conventional coal power investors, to transform their business towards a clean and low carbon future. Especially with the further decreasing 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 further argue that with the achieving of grid parity, solar PV will become the predominant RE power in China's energy market. Solar power has low requirement of physical infrastructure and could be built as a stand-alone energy system, which doesn't need a large piece of land. It could also fit onto the rooftop of existing buildings, a huge advantage compared to traditional large-scale power plants. These characteristics make it suitable for relieving the energy supply pressure in large electricity loading areas, such as in the southern part of China (interview insights, senior experts from solar PV industry association, Beijing, 23th Nov 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 mobilised the development of distributed solar PV energy system as a strategy to alleviate poverty in China with an objective to add 10GW capacity to benefit the 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 installed electric technology in China.

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 co-evolves with different phases of niche development.

5.1 Weak alignment and slow niche development

The two cases have illustrated that the weak alignment between niche and regime actors' expectations match with the low speed and scale of niche development. Before 2007, when there was weak alignment between niche and regime actors, there was relatively low taking up of wind and solar power (see Fig. 5). The narrowly shared expectations at the niche level explains why at this stage, the policy goals set up by the central government for wind power could not be achieved.

The weak alignment attributes to the 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, as a result there was limited taking up of solar power compared with wind power. With relatively high 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 which requires to shift the energy system towards clean and low-carbon.

5.2 Medium-strong alignment and moderate niche development

The two cases evidenced that the medium-strong alignment contributes to moderate niche development. However, niche and regime actors hold different types of alignment in the two cases. In the wind power case there was relatively 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 have similar broadness of alignment at both niche and regime levels. Between 2008 and 2010 the development of wind power could be seen as an add-on to the market. Because of the less broad alignment at the regime level, which we see later on, 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 further 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 hydro power and nuclear power, the fast decreasing of solar panel costs burgeoned the expectations of the competitive advantages of solar PV in the market.

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, the expectations could be translated into the 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>. It articulates the long-term development targets for installed capacity of wind power to achieve 400GW (by 2030) and 1000GW (by 2050). Moreover, we see more articulations of connecting the development of wind and solar power with the sustainable and clean development at the landscape level. Especially when the clean and low-carbon is widely shared in society, the scenarios with high proportion of wind and solar power in the electricity system were generated to further require actions from corresponding actors. Evidenced by the report issued by Energy Research Institute of NDRC (2015) it further articulated the prospective visions and scenarios that China needs towards a low-carbon transition.

Furthermore, when the central government share the expectations, it is more likely to implement supporting institutions for niche development. For example, to further stimulate support from the grid company towards wind and solar power, in 2016 the central government set minimum generation hours per year of 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 expectations were more stabilised and translated into institutions to support wind and solar power's further development. For example, the central government implemented stringent policy to cap coal power to create space for RE deployment and to aid meeting the targets set for the non-fossil fuel in the energy mix in 2020. This institutional change contributes further to the fast wind and solar power deployment and constrains thermal power plants deployment.

This strong alignment between niche and regime actors creates 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 substitute the 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 Fig. 5, the percentage of yearly new installed capacity of thermal power keeps decreasing and it 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 the coal power investors' expectations of the strategic role of thermal power in the future electricity market. Furthermore, with stringent policy regulation from the central government, the coal power regime actors started to question the resilience of the regime. This provided further opportunities for niche actors to articulate potential solutions by the two RE technologies. This strong alignment explains why China's wind power and solar PV installed capacity has surpassed its 2020 goals three years ahead of schedule (Finamore, 2019).

6. Conclusion

This paper endeavours to make a first step to contribute to unfolding the alignment dynamics between niche and regime actors' expectations, and how their alignment dynamics contribute to niche acceleration. Our contribution is fourfold. **Firstly**, we conceptualise three alignment patterns between niche and regime actors' expectations: strong alignment, semi-strong alignment and weak alignment. **Secondly**, we define three different phases of niche accelerations based on the technology adoption lifecycle studies, and relate them to the three alignment patterns. **Thirdly**, we operationalise our conceptual framework by specifying different phases of niche accelerations, corresponding niche and regime actors in our cases, and thresholds to define different alignment patterns. **Fourthly**, we illustrate the alignment dynamics between niche and regime actors' expectations into two cases, wind and solar power development in China between 2000 and 2017. Overall, this paper provides a theoretical framework that clarifies how the expectation alignment between niche and regime actors contributes to niche development, including its acceleration. Based on our results we would even argue that alignment dynamics among niche and regime actors' expectations can be seen as a good proxy for expected niche development.

Our research results challenges the dominant state-led understanding of China's fast RE development and supports a host of 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 with our framework as a result of relatively weak alignment between niche and regime actors' expectations. Post 2007 the alignment between the two has increased, leading to surpassing of the central government's goals. Thus, evolving coordination and alignment processes between different stakeholders are important, also in a country such as China. We argue that the proposed conceptual framework can be used for other cases too, outside China. But obviously this would need new research.

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Appendix

Table A1 List of interviewees (31 interviewees - based on the categories of main stakeholders).

Categorises	Organization name& expert position	Date & venue
Wind power manufacturing industry	Technological experts and also the managers in big wind power manufacturing company	17 Aug 2017, Netherlands
NGOs	Greenpeace (2 experts: researcher and manager on coal power development)	10 Oct 2017, Beijing
Renewable Energy Researcher	North China Electric Power University, Professor	18 Oct 2017, Beijing
Renewable Energy Generator	China Longyuan Power Group Limited, Managers and investors (3 experts)	22 Oct 2017, Beijing
Renewable Energy Generator	China General Nuclear Power Group (CGN), Investor and manager	4 Nov 2017, Beijing
Central government	National Development and Reform Commission (NDRC), policy maker	10 Nov 2017, Beijing
Central government	Energy Research Institute, NDRC, researcher	14 Nov 2017, Beijing
Wind power Industry association	Chinese Wind Energy Association (CWEA), Director	17 Nov 2017, Beijing, Telephone
State Grid company	Energy research institute of State Grid Corporation of China (SGCC), Researcher	18 Nov 2017, Beijing
Energy Research institute	CAS (decentralized energy system research), Director, Technicians	18 Nov 2017, Beijing
Solar PV industry association	China Photovoltaic Industry Association (CPIA), Director	23 Nov 2017, Beijing
Wind power industry association	Global Wind Energy Council, Director	24 Nov 2017, Beijing, Skype
Electric Power Generators	China Energy Investment Corp., Director of Strategic Planning office	1 Dec 2017, Beijing
Central Government	former policy makers in the central government	12 Dec 2017, Beijing
Central Government	Renewable Energy research centre, Research institute of NDRC, director	14 Dec 2017, Beijing
Solar Power Industry Association	China Photovoltaic Industry Association (CPIA), Secretary-general	21 Dec 2017, Nanjing
Electric Power Generator	Shanghai Electric Power Company, regional Manager	21 Dec 2017, Nanjing
Renewable Energy Industry Association	Chinese Renewable Energy Industries Association, President	22 Dec 2017, Nanjing
Wind Power Industry Association	Chinese Wind Energy Association (CWEA), Secretary-general	23 Dec 2017, Beijing
Solar PV Research Institute	National Laboratory of Trina Solar, Director	27 Dec 2017, Beijing-Telephone
Solar PV development	Xi'an Jiaotong-Liverpool University, Researcher	31 Dec 2017, Suzhou
Wind power Manufacturing industry	Sinovel Wind Power Co., Regional manager	6 Jan 2018, Nantong
State Grid company	State Grid Corporation of China (SGCC), Manager	7 Jan 2018, Beijing
Electric power industry association	China Electricity Council, Secretary-general	10 Jan 2018, Beijing- through phone
Solar Power technology	Chinese Academy of Sciences, Technicians	12 Jan 2018, Beijing
Solar PV manufacturing	Solar PV manufacturing firm, Regional manager	23 Jan 2018, Beijing
Solar PV industry association	Solar PV industry association, Vice Secretary in General	23 Jan 2018, Beijing
State Grid company	State Grid Corporation of China (SGCC), Director	3 Feb 2018, Beijing

Table A2 China's renewable energy cumulative installation targets for 2020 from different planning regimes.

2020 targets (installed capacity)	Medium and Long-term development plan for renewable energy	Energy Development Strategic Action (2014-2020)	Energy Development 13th FYP	Energy Production and Consumption Revolution Strategy (2016-2030)	2015 Levels
Issued organization	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 [6] by 2010, 1.8GW by 2020.	100GW	110-150GW		43GW (43.18)

[6] It includes solar PV and solar thermal together.

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 power		Reduce the share of coal power in the electricity mix to lower than **62%** by 2020.	Reduce the share of coal power to less than **58%** by 2020.	Primary energy consumption of coal power should be capped below 6 billion tce;	

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