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A comparative approach to local organisation of the energy transition

Master Thesis for the attainment of the academic degree of Master of Science

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Abstract

In recent years, numerous renewable energy cities were established worldwide, piloting different pathways to transition to clean energy. With the ability to address local needs more precisely in their unique geographic, social and economic contexts, cities play a vital role in implementing overall climate mitigation goals on the local level. In China, many renewable energy cities have emerged as well. However, official documents suggest that Chinese government authorities establish such renewable energy cities strategically, which leads to the assumption that the impulse to become renewable is different from other countries, where bottom-up initiatives are more common. Hence, this thesis explores answers to the question why and how the Chinese government promotes the energy transition of Chinese cities and regions. To comprehend the dynamics of local energy transition projects, this thesis adopts two frameworks from the field of sustainability transitions, the *multi-level perspective* and *strategic niche management*, and applies them to seven European and two Chinese case studies. The European sample includes the cities Graz, Güssing, Freiburg, and Helsinki as well as the communities Feldheim, Jühnde and Murau. The Chinese sample consists of the bottom-up initiative Shaanxi Sunflower Project and the demonstration project Tongli New Energy Town. A comparative analysis evaluates in how far the cases correspond to the multi-level perspective or strategic niche management. The comparison of the case studies reveals that the development of renewable energy cities in China goes beyond a top-down vs. bottom-up logic. In the Chinese context, strategic niche management should be understood as *experimentation under hierarchy*, which serves at pretesting different approaches before rolling them out nationwide. In addition, the analysis shows that both the multi-level perspective and strategic niche management have their advantages and disadvantages for niche development. Niches following the logic of the multi-level perspective may result in higher stakeholder acceptance, whereas strategic niche management can in turn accelerate niche development. However, since natural niche development cannot be steered intentionally, decision-makers who intend to induce local renewable energy projects have no other option but to resort to strategic niche management. To increase stakeholder acceptance and thus to improve the project outcome, decision-makers are advised to accommodate sufficient room for stakeholder participation in the project design.

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dena	Deutsche Energie-Agentur
DES	Distributed energy system
DRC	Development and Reform Commission
FOE	Friends of the Earth
FYP	Five Year Plan
GDP	Gross domestic product
GHG	Greenhouse gas
Gt	Gigatonnes
ha	hectares
ICLEI	International Council for Local Environmental Initiatives
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
Jiangsu Electric	State Grid Jiangsu Electric Power Co. Ltd.
kW	Kilowatts
MLP	Multi-level perspective
MMHB	Mama Huanbao (Shaanxi Volunteer Mothers Association for Environmental Protection)
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
NDC	Nationally Determined Contribution
NDRC	National Development and Reform Commission
NEA	National Energy Agency
NGO	Non-government organisation
PV	Photovoltaic
RE	Renewable energy
REC	Renewable energy city
SAFA	Finnish Association of Architects
SDG	Sustainable Development Goal
State Grid	State Grid Corporation of China
SNM	Strategic niche management
STA	Sustainability transition approach
Suzhou Power	Suzhou Power Supply Company
t	tonne
TNET	Tongli New Energy Town
UN	United Nations
WETDZ	Wujiang Economic and Technological Development Zone

1. Introduction

In light of the ever-present impacts of climate change, the Paris Agreement and the most recent special report by the Intergovernmental Panel on Climate Change (IPCC) are urging for increased efforts to limit climate warming to 1.5 degrees Celsius.[1] As climate change is a global challenge, all countries must join forces to mitigate climate warming above the afore-mentioned temperature increase.[2] As a result of the Paris Agreement, signatory countries have been asked to formulate *Nationally Determined Contributions* (NDCs) in which they determine country-specific efforts for climate change mitigation.[3] However, there are not solely mitigation goals on the international and national level. Local initiatives on city or community levels have emerged too, showing significant potential to contribute to climate change mitigation.[4] With the ability to act more promptly than international governmental and non-governmental political institutions, and to develop solutions tailored to local conditions, local approaches have shown to be better suited for multiple fields of actions within climate change mitigation.[5]

Energy transition constitutes one of these fields. The energy sector was the largest emitter of greenhouse gases (GHG) in 2016 and under the seventh Sustainable Development Goal (SDG) *Affordable and Clean Energy*, the United Nations (UN) attributed major climate change contributions to the energy sector, indicating that it accounted for roughly 60 percent of total global GHG emissions.[6] Nonetheless, all vital economic and political activities rely on access to energy, be it agricultural activities or employment.[7] This is another reason why the energy sector is a critical focus area of sustainable development, and why it is indispensable to transition towards renewable energy (RE).

Since local conditions vary greatly across cities and communities, resulting from differences in topography, geography and demography, localities know best how to tailor the energy transition to local needs. Hence, local communities play a crucial role in the national and eventually global energy transition, making the energy transition a bottom-up agenda.[8] Numerous *eco-cities*, *renewable (energy) cities* and related projects on city and community levels have emerged, piloting local paths towards an increasingly renewable energy mix. Among them, certain cities even aim to become 100 percent renewable, and are thus termed *100 percent renewable energy cities*.[9]

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[1] United Nations 2015, p. 3; Intergovernmental Panel on Climate Change 2018.
[2] Feulner 2015, p. 5; United Nations 2015, p. 2.
[3] United Nations 2015, p. 3.
[4] Defrancia 2018.
[5] Droege 2006, p. 9.
[6] International Energy Agency 2018a; United Nations. It should be noted, however, that the UN do not indicate a year for this number.
[7] United Nations.
[8] See Lou 2013, p. 33.
[9] Lou 2013, p. 31.

As the largest emitter of energy-related GHG in 2016, China faces particular pressure to transition towards renewable energy.[10] Although many Chinese cities have joined the increasing number of *renewable energy cities* (RECs), the fact that the strategic establishment of RECs is explicitly enshrined in official documents leads to the assumption that the impulse to become renewable is different from bottom-up RE initiatives in other countries.[11] A purely top-down approach to diffuse the energy transition in Chinese cities and communities seems equally unlikely, since decentralised, i.e. distributed energy generation provides significantly higher efficiency gains.[12] City and community-specific characteristics mentioned above and the nature of distributed energy generation thus require the energy transition to translate into local transition projects, and this thesis aims to explore the dynamics of this process.

Based on the theory of sustainability transitions, which attempts to comprehend drivers behind system transitions, RECs and related local initiatives can be understood as niche experiments, i.e. tools to test policy options before rolling them out nationwide. The aim of this thesis is to comprehend why and how the Chinese government promotes the transition of Chinese cities and regions towards 100 percent RE in the context of niche experimentation. For this purpose, two Chinese RECs will be investigated and projected onto a benchmark derived from international projects to specify to what extent the Chinese case is similar to or different from international practices of REC implementation. Results of this analysis may be relevant for other countries and thus for the global energy transition as well.

For a better understanding of the energy transition, chapter 2 will begin by outlining the theory of sustainability transitions with a special focus on the concepts of the *multi-level perspective* (MLP) and *strategic niche management* (SNM). After explaining the major components and dynamics of these two concepts, the chapter will provide an introduction of the energy transition, define *renewable energy* (RE) and demonstrate the relevance of the energy transition for sustainable development with a status quo on the environmental impacts of energy production and consumption. This will lay the groundwork for investigating current challenges in the Chinese energy sector which give reason to promote an energy transition in China. Against this backdrop, chapter 2.2.3 will highlight the role of so-called *renewable energy cities* (RECs), i.e. renewable energy initiatives on the levels of regions, cities and communities both within the broader energy transition and within the framework of the MLP. With regard to the Chinese context, this chapter will put emphasis on the relevance of pilot experimentation for the evolution of Chinese RECs.

Chapter 3 will proceed by applying the MLP framework onto both the global and the Chinese socio-technical energy system. The first part will first holistically assess landscape drivers and regime elements in the international energy system, while referring to the six regime elements

[10] International Energy Agency 2018b.
[11] Lou 2013, p. 31; Lou 2015, p. 404.
[12] Droege 2006, p. 90.

of the MLP framework. The niche level analysis will draw from a multi-case report of seven European RECs which were selected according to the availability of detailed records and final results. To answer the question of how these niches evolved, the analysis will first follow four criteria which were developed to provide for sufficient comparability of the cases and subsequently be compared with Geels' (2004) four phases model of niche development. In the second part, the Chinese energy system will be analysed using the same method, underpinned by two comprehensive case studies. The first case study of Shaanxi *Sunflower Project* was selected to represent a grassroots initiative, whereas the second case of Tongli New Energy Town describes a pilot project selected by government authorities.

The analysis of the European and Chinese cases will be summarised in the Results section regarding the original question of why and how nations promote the development of RECs. The comparison of the findings also allows for identification of similarities and differences between European and Chinese RECs with regard to the designs and the development of niches, insights of which can consequently flow into the theoretical background. Hence, this thesis will not only conclude by answering the research questions, but derive implications for both future research on the relevant theoretical groundwork and practitioners.

2. The sustainability and energy transition

To grasp of the nature of the sustainability and energy transition, it is helpful to understand transitions in general. A basic characteristic of all transitions is that they constitute a 'passage from one state, stage, subject, or place to another', or 'a movement, development, or evolution from one form, stage, or style to another'.[13] Theories on transitions and system innovations have become particularly relevant for the discourse on sustainability, as they offer potential for transitions aimed at sustainable development, with critical implications for actors from politics, civil society and businesses.[14]

Transitions are possible on different levels and in different scales. An example of a transition at the macro-level, on which societies transform as a whole, is the transition from rural to industrial societies. Transitions at the micro-level manifest in shifting 'societal functions', which Geels et al. (2004) illustrate with two examples: 1) replacing horse-and-carriage with motorized transport and 2) changing from telegraph to telephone.[15] These examples suggest that transitions of societal functions are often initiated by technological replacements. Hence, at the core of their research, Geels et al. (2004) investigate transitions driven by changes in so-called *socio-technical systems*, i.e. by reciprocal effects between technological innovation and social elements.

[13] Merriam-Webster 2019, transition entry.
[14] Geels et al. 2004, p. 1.
[15] Geels et al. 2004, pp. 2–3.

While it is undeniable that technological innovation plays a major role for sustainable development in many fields, efforts to mitigate climate change must not focus on the technical side alone. Instead, research has been asking to develop measures for a holistic sustainable development which integrate all areas of human interaction, including economics, politics, consumption and social behaviour.[16] Taking energy as an example, this would mean that efforts should not solely focus on improving energy efficiency but should also attempt to phase out the use of unsustainable energy sources, and to change electricity consumption patterns in both industrial businesses and private households.

Yet, some practices are easier to adjust than others. Old technologies, for instance, can be replaced by sustainable innovations, and economic practices can be regulated or equipped with different incentive structures to prevent pollution or degrading working conditions. However, aspects related to cultural traditions, norms, values and mindsets of individuals and groups are obviously more difficult to influence. In his research, Geels (2004) has combined different approaches and bodies of literature to comprehend transitions and introduced the multi-level perspective (MLP) on sustainability transitions. His integrative approach is helpful to understand the different levels and factors influencing system transitions, while taking economic, political, technological and social elements into account with equal emphasis. The following section will first explain the concept of the MLP, before applying it to the comparative analysis of the energy transitions in Europe and China in chapter 3.

2.1. Sustainability transitions and the multi-level perspective

The MLP is a concept overarched by the field of *sustainability transitions*, which can be defined as 'long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption'[17], while the MLP aims to comprehend drivers of such transitions. Different literature strands and approaches have derived from the *sustainability transitions approach* (STA), partly offering more concise frameworks to analyse specific aspects of transitions, partly attempting to develop appropriate tools that enable active management of transitions.[18] **Figure 1** shows core concepts relevant to this thesis.[19] The upper branch names the key analytical framework, the *socio-technical system*, and its derivative concept, the MLP. The main idea behind socio-technical systems is that technical innovations are embedded in social contexts, resulting in reciprocal effects on technological and social developments. The concept of

[16] Köhler et al. 2017, pp. 1–2. Köhler et al. agree that sustainable change goes beyond merely introducing novel technologies. Change needs to extend onto dominant economic, social and political institutions as to achieve responsible and sustainable changes in behaviour across different stakeholders, and to promote a more thoughtful use of resources.

[17] Markard et al. 2012, p. 956.

[18] Fischer 2010, p. 291.

[19] The arrangement of the concepts does not correspond with a chronological order, but is rather an attempt of logical classification.

transition management on the lower branch investigates possibilities to actively manage and direct transitions.[20] Its implications are highly relevant for decision-makers when formulating sustainable strategies.

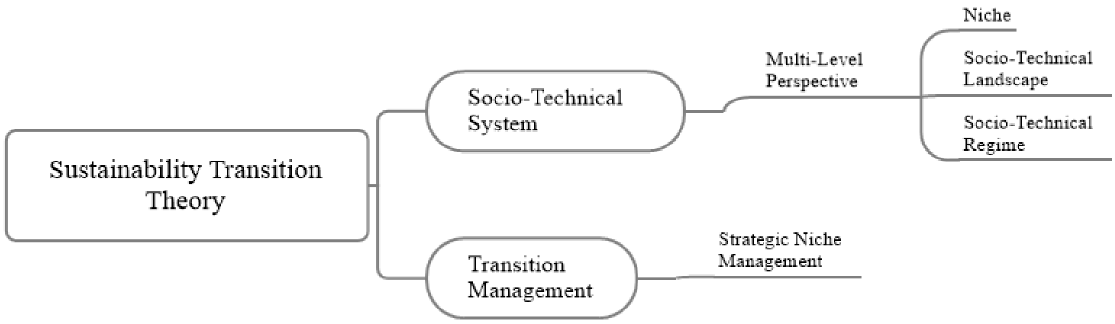

Figure 1 Relevant research strands within the field of STA. (Adapted from Markard et al. (2012), p. 957)

To comprehend sustainability transitions, the concept of socio-technical systems identifies socio-technical *regimes*, *landscapes* and *niches* as levels on which drivers for transitions accumulate. **Figure 2** illustrates the interplay of the three levels and their dynamics. At the niche level, learning processes and improvements in the price-performance ratio of an innovation create momentum. The novelty integrates into existing structures by linking up to other elements.[21] Hereby, the novelty becomes increasingly entrenched in the niche, and elements around it consolidate towards one dominant design. At the same time, emerging changes on the landscape level exert pressure on the regime. These dynamics from the niche and landscape levels lead to a destabilisation on the regime level, from which *windows of opportunity* for the technological novelties emerge.[22] While the regime adjusts to the new circumstances, i.e. while it *transitions*, it may in turn exert influences onto the landscape. However, as discussed before, it is unlikely that these influences are steerable.

[20] However, there is doubt whether it is possible to intentionally steer transition processes. Rather, dynamics within transitions are aligning to each other and thereby self-coordinating. Geels and Schot 2007, p. 402.
[21] Geels 2004, pp. 41–42.
[22] Geels and Schot 2007, p. 400.

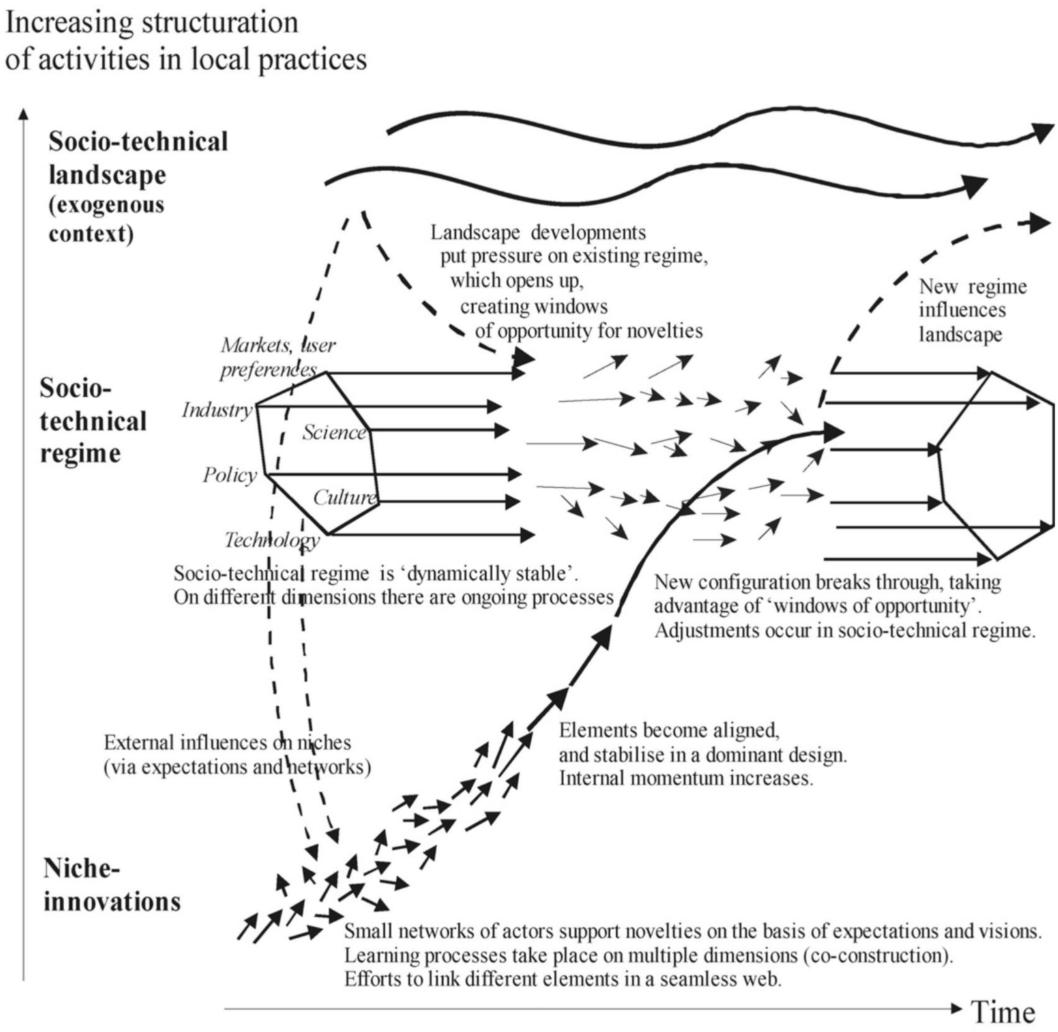

Figure 2 The multi-level perspective on transitions. (Geels and Schot 2007, p. 401)

Geels (2004) describes the relations between the regime, landscape and niche as a 'nested hierarchy', indicating that niches are embedded in regimes, which are in turn embedded in landscapes (see **Figure 3**). In regimes, linkages between elements emerge, resulting in increased stability, but also in greater difficulties for new technologies to permeate and disseminate. Arrows between niche novelties and regimes signify that these novelties are especially designed to solve problems in existing regimes.[23]

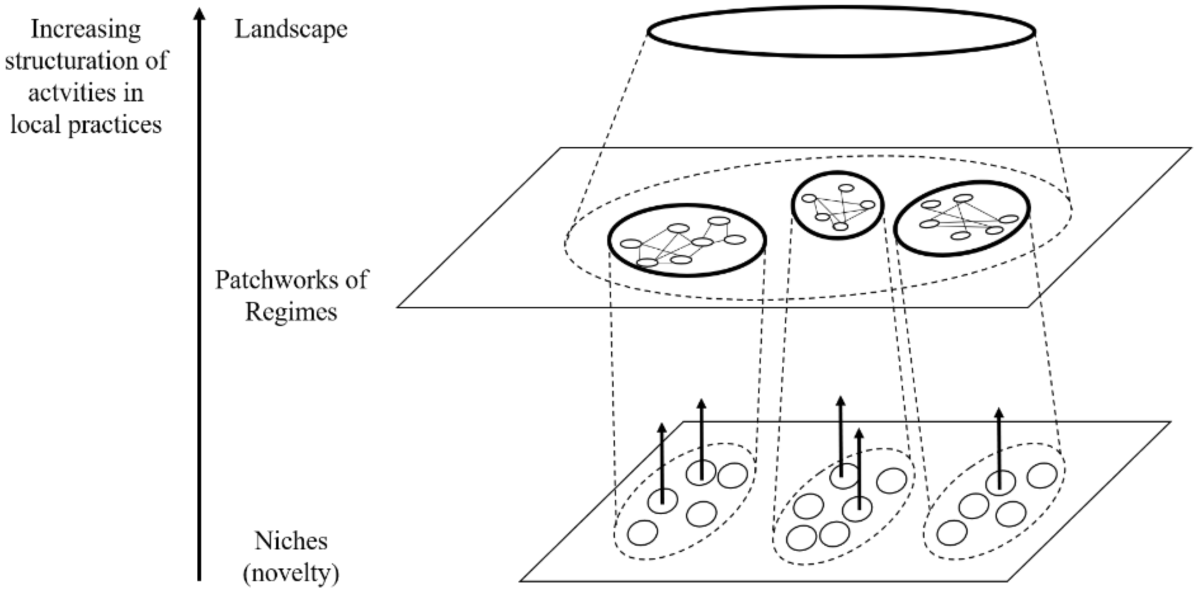

Figure 3 Nested hierarchy of landscapes, regimes and niches. (Geels 2004, p. 36)

2.1.1. The socio-technical landscape

The *socio-technical landscape* surrounds actors in niches and regimes, thereby working as their external environment for technological trajectories.[24] The landscape changes slowly and purposeful influences on it are rather improbable.[25] Geels (2004) illustrates the concept with the following examples:

> The socio-technical landscape contains a set of heterogeneous, slow-changing factors such as cultural and normative values, broad political coalitions, long-term economic developments, accumulating environmental problems growth, emigration. But it also contains shocks and surprises, such as wars, rapidly rising oil prices.[26]

All these examples are external factors which evolve over time. Whereas it is unlikely that the regime has purposeful influence onto the landscape, landscape dynamics can in turn exert pressure onto the regime, leading to *windows of opportunity*, in which changes on the niche level may permeate and change the regime. Dynamics on the niche level and how they dovetail with the landscape and regime levels will be explained below.

[23] Geels 2004, p. 36.
[24] Fischer 2010, p. 292; Geels 2004, p. 34.
[25] Geels 2004, p. 35.
[26] Geels 2004, p. 34.

2.1.2. The socio-technical regime

The concept of the *socio-technical regime* refers to the coordination of activities in a network in which technological innovations are embedded and which is composed of different actors, institutions and their rules. Resulting from an emphasis on technologies in previous research, literature had consequently focused on a small group of technical experts in the past. In more recent research, however, the group of stakeholders with potential influence on technical developments also includes actors and institutions from markets and industries, politics and society as well as science and technology, which are represented in **Figure 2**. These stakeholder groups act according to different, yet compatible rules, which guide and coordinate their activities. The coordinating function of socio-technical regimes ensures stability within the socio-technical system, which is commonly visualised as trajectories developing in similar directions, representing parallel behaviours and activities in the regime. Consequently, diverging trajectories due to uncoordinated activities of the involved social groups cause instability for the socio-technical regime.[27] This instability is particularly vital for technological novelties to permeate a regime from the niche level. Since established practices in the regime are already entrenched in its institutions, organisations, economics and culture, it is difficult for technological innovation to break these practices up and disseminate in the regime. Yet, uncoordinated or even conflicting developments within regimes may open *windows of opportunities*, through which the innovation may gain foothold in the regime and potentially cause broader changes. Such radical innovation is rather found on the next level, the *socio-technical niche*, whereas innovations on the regime level are limited to incremental improvements.[28]

2.1.3. The role of the niche

The MLP logic of niche development

The MLP has incorporated the already existing concept of *niches*, thus extending the view on transitions by a micro-level or *bottom-up* perspective.[29] The idea behind niches is to provide protected space for innovations which would most likely be marginalised if they were commercialised under market conditions. Transferring this concept to the context of STA would mean that protection is granted for experiments which challenge the socio-technical regime with potentially sustainable outcomes.[30] Throughout this thesis, the niche innovation will not merely refer to the introduction of RE to cities, but rather the establishment of such cities and regions which are striving to rely on RE in all key areas (see chapter 2.2.3).

[27] Geels 2004, pp. 33–34.
[28] Geels 2004, pp. 35; 37–39.
[29] Geels and Schot 2007, p. 400; Markard et al. 2012, p. 957; Markard et al. 2012, p. 958.
[30] Fischer 2010, p. 294.

According to Geels (2004), the development of technological innovations on the niche level is characterised by four phases (see **Figure 4**). In the first phase, a new technology emerges, often serving to solve specific problems in existing regimes. As long as it develops within the niche, it remains mostly invisible on the other levels. In the meantime, the new technology is constantly being improved through experimentation and adapting to user needs. In the second phase, niche communities, i.e. expert groups evolve, conducting further research to incrementally improve the new technology. The innovation gains momentum and develops a distinctive trajectory, whereas regime influences on the novelty's design and functions diminish.[31] Such niche communities are comprised of 'dedicated actors', often consisting of 'outsiders or fringe actors.'[32] These local actors and their networks are a crucial driver behind the development of niche innovations. In the third phase, the innovation improves in terms of economic factors influencing its further diffusion, such as cost effectiveness, but also compatibility with other technologies. As soon as the novelty competes on the mainstream market, it challenges the existing regime. Competitors may begin to imitate the new technology or compete in developing innovations. Hereby, other actors in the regime get involved, influencing their behaviour and potentially reshaping the established regime. Finally, in the fourth phase, the new technology replaces the old one. Incremental improvements further enhance the technology's cost effectiveness, thus supporting its adoption rate. Also, the innovation may extend onto different market segments.[33] While innovation in regimes is of incremental nature, niches may incubate more radical innovation due to the afore-mentioned protection from market selection. These radical niche-level innovations can permeate the socio-technical system, when processes at the regime and landscape levels create a *window of opportunity*.[34]

[31] Geels 2004, pp. 40–41.
[32] Geels and Schot 2007, p. 400.
[33] Geels 2004, pp. 41–42.
[34] Geels 2004, p. 35; 37.

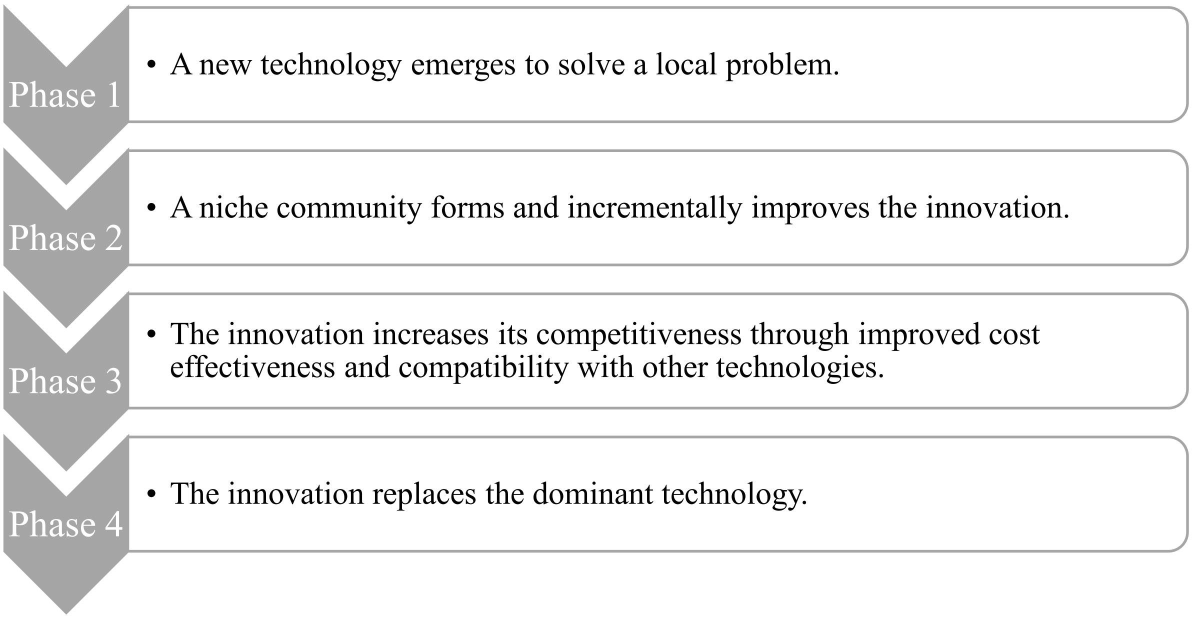

Figure 4 The four phases of niche development. (Own illustration based on Geels (2004), pp. 39-42)

Niche formation through strategic niche management

As opposed to the MLP, which describes a spontaneous emergence and dynamic development of niches, the second research strand within the STA, *transition management* (see **Figure 1**), has been investigating possibilities to establish niches strategically and to instigate changes on the regime level by active management. A concept derived from transition management is *strategic niche management* (SNM), which is defined as 'the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of 1) learning more about the desirability of the technology, and 2) enhancing the development and rate of application of the new technology.'[35] Hence, based on the logic of niches offering protected spaces for technological innovations, strategic niche management aims at enabling and managing these protected spaces.[36]

To strategically manage sustainable changes, Kemp et al. (1998) proposed three strategies for policy-makers. The first strategy suggests changing incentive structures behind market forces. Policy-makers can bring about radical behavioural changes with environmentally benign outcomes by 'tax[ing] negative externalities and reward[ing] positive externalities'. As Kemp et al. (1998) implicitly criticise, however, policy-makers often focus too much on finding new technologies to solve certain problems, instead of adjusting existing configurations in the regime. This approach requires drastic measures, whereas the effects of such financial incentives are not necessarily sufficient to instigate a broader regime change.[37] The second strategy recommends preparing the launch of a new socio-technical regime as if it were a market entry. Yet, this approach is restricted by the fact that socio-technical regimes are too complex

[35] Schot et al. 1999.
[36] Kemp et al. 1998, p. 186.
[37] Kemp et al. 1998, pp. 184–185.

and interrelated with other aspects of social organisation to be planned. Just as it is difficult for firms to plan the successful commercialisation of an innovation, the success of a strategically induced transition remains unpredictable.[38] The third strategy relies on 'on-going dynamics of socio-technical change', exerting controlled pressure to steer these dynamics into the desired direction. In this approach, policy-makers can get involved actively in the process of socio-technical change, which includes 'creating room for experimentation and variation', as well as avoiding the dominance of certain actors.[39] The notions of these different strategies will be useful for the analysis of RECs.

Nevertheless, there is controversy around the question if niche dynamics and broader transitions can be directed in a specific direction at all. Geels et al. (2004) argue: 'Public authorities are just one societal group among several others. Like other groups, they have limited power, a limited cognitive perspective and limited resources to influence system dynamics.' [40] Accordingly, the authors negate the possibility of politics to strategically induce and steer transitions. Against this criticism, the SNM approach stresses the involvement of a broader group of stakeholders throughout the process of niche development, particularly emphasising the role of the users of an innovation. Users contribute significantly to learning processes, results of which can then subsequently enter institutionalisation.[41]

Institutionalisation is another key component of SNM. Rather than focusing on experimenting with a technological novelty alone, SNM strives to integrate the innovation in existing institutions as to enable learning processes which further enhance the new technology.[42] This is particularly critical in light of the fact that the need to transition towards cleaner energy is on the agenda of multiple countries and multi-lateral coalitions. For instance, the German Federal Government has coined the term *Energiewende* and aims to turn it into a driving force for the country's economic and infrastructural activities. Subsequently, the German Ministry of Economy and Energy (BMWi) has developed an 'energy concept', which breaks down necessary targets across the political, strategic and coordination levels.[43] Similarly, the aim to transition towards clean energy under the SDG 7 *Affordable and Clean Energy* connects all signatory countries.[44]

Nevertheless, SNM is not just a political task. Instead, niche managers can come from various backgrounds, such as politics, industry, and civil society. Depending on core competencies, actors such as NGOs or industries may be more qualified for certain processes. For instance, whereas governments are better at regulating the niche, NGOs may be more appropriate for the

[38] Kemp et al. 1998, p. 185.
[39] Kemp et al. 1998, pp. 184–185.
[40] Geels et al. 2004, p. 8.
[41] Kemp et al. 1998, p. 186.
[42] Kemp et al. 1998, p. 186.
[43] Bundesministerium für Wirtschaft und Energie 2019a; Bundesministerium für Wirtschaft und Energie 2019b.
[44] United Nations.

actual execution of niche projects. However, an important notion is that SNM is a collective task, rather than in the hands of a single individual or organisation. Although it is possible that some actors are more dominant than others, SNM requires inclusive negotiations with all parties involved.[45] For the afore-mentioned reason that governments may engage in SNM to achieve their energy agendas, this has important implications for the design of the niches. A set of different niche designs will be introduced in chapters 3.1.3 and 3.2.3. Before, chapters 3.1 and 3.2 will apply the MLP approach to the case of energy transitions in Europa and China, by identifying drivers and influences on the different levels. However, to better understand why it is indispensable to transition towards cleaner energy, chapter 2.2 will first provide a status quo of the energy sector in a global and a Chinese context.

2.2. The energy transition

To understand the role of energy in the context of sustainable development, it is critical to distinguish fossil fuels and renewable energy sources. To this end, the National Renewable Energy Laboratory provides a useful classification of different energy sources (see **Figure 5**).[46] Based on this classification, renewable energy sources in this thesis include solar, wind, geothermal, hydro and both biomass and biogas energy.

renewable	conditionally renewable	to be clarified	non-renewable
• solar • wind • geothermal • hydro	• biomass • landfill gas • sewage gas • biogas	• waste to energy • coal mine methane	• nuclear • natural gas • coal • oil

Figure 5 Classification of energy sources. (Own illustration based on National Energy Laboratory (2015), p. 2)

Energy is one of the fields of actions with the largest potential to induce changes for more sustainable social and economic structures.[47] Accounting for roughly 42 percent of total global GHG emissions in 2016 (see **Figure 6**), the energy sector is a major contributor to climate change.[48] Whereas CO_2 emissions slightly declined between 2014 and 2016, presumable due to improved energy efficiency and a broader use of low-carbon technology across countries which were able to curb coal demand, global economic growth eventually surpassed energy productivity between 2017 and 2018. Therefore, CO_2 emissions increased in 2017, although RE and nuclear energy contributed to the decoupling of emissions growth from energy

[45] Kemp et al. 1998, pp. 188–189.
[46] National Renewable Energy Laboratory 2015, p. 2 According to this classification, conditionally renewable energy sources indicate that the suitability of these energy sources for renewable energy projects depend largely on local conditions. Energy sources that yet need to be clarified comprise '[t]echnologies remaining under consideration', i.e. which are not renewable in the stricter sense.
[47] Köhler et al. 2017, p. 2.
[48] Moomaw et al. 2012, p. 164.

demand.[49] Especially in 2018, global energy consumption grew at a pace of 2.3 percent compared to 2017, a growth rate twice the average since 2010. Reasons for this unprecedented speed have been strong global economic growth, along with changing weather conditions in certain regions which have increased the demand for heating and cooling. Resulting from the growing energy consumption, CO_2 emissions amounted to 33.1 gigatonnes (Gt) in 2018, thus reaching a new high with a growth rate of 1.7 percent compared to the previous year.[50] According to IEA's estimations, global energy demand is yet to increase due to rising incomes and population growth, leading to a demand growth of more than 25 percent by 2040.[51]

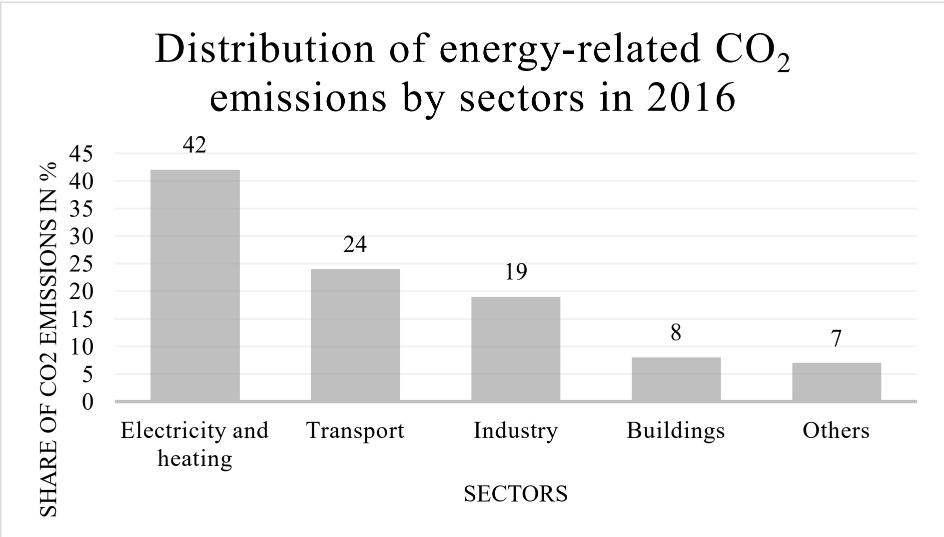

Figure 6 Distribution of energy-related CO_2 emissions by sectors in 2016. (Adapted from Statista (2018))

The increase in global CO_2 emissions related to the growing energy demand has verifiable effects on global climate warming. The IEA found that CO_2 emissions from coal combustion accounted for more than 0.3°C of the 1°C global average temperature increase compared to pre-industrial levels. Thus, coal has become the major source of global temperature increase.[52] Coal-fired power generation continues to be the single largest emitter of CO_2, accounting for 30 percent of all energy-related CO_2 emissions and 56.6 percent of all anthropogenic GHG emissions.[53]

The energy transition, defined as 'a radical reconfiguration of the way we generate and use energy in cities and beyond'[54] has shown significant effects to contribute against climate

[49] International Energy Agency 2019, p. 7.
[50] International Energy Agency 2019, p. 4. BP estimations are even higher, with total global CO_2 emissions amounting to 33.9 Gt in 2018. See BP 2019, p. 57.
[51] International Energy Agency 2018c.
[52] International Energy Agency 2019, pp. 7–8 'Pre-industrial' levels are commonly used as a reference for global mean surface temperature (GMST) during the period of 1890-1900. See Intergovernmental Panel on Climate Change 2018, p. 24.
[53] International Energy Agency 2019, p. 4; Moomaw et al. 2012, p. 164.
[54] Rohracher and Späth 2014, p. 1416.

warming internationally. By increasing the use of RE technology, the energy transition was able to avoid 215 million tonnes (Mt) of emissions in the power sector in 2018. These emission savings can largely be attributed to energy transition measures in China and Europe. Together, their emission savings accounted for two-thirds of total global emissions saved through RE. The transition towards renewable energy sources in 2018 was already able to cut emissions growth by 50 percent.[55] Although global renewable energy generation increased from 490.2 Mtoe in 2017 to 561.3 Mtoe in 2018 and thus accounted for a growth rate of 14.5 percent, the global expansion of RE still falls behind global electricity demand.[56]

Therefore, it remains imperative to support and accelerate the expansion of RE technologies as to further reduce GHG emissions and limit climate warming. The positive results of the energy transition on climate change mitigation suggest that the energy transition is an effective approach to both limit GHG emissions and global temperature increases. Following this logic, countries should engage more actively to advance energy transitions on a national level, eventually joining forces for an international energy transition.

For a better understanding of what forces are in play in the energy transition, section 2.2.1 will provide a general overview of the socio-technical energy system illustrated with the MLP framework, before transferring the framework to the global and the Chinese energy systems throughout chapter 3.

2.2.1. The socio-technical energy system

With this potential to contribute to climate change mitigation, the energy transition can be seen as one development among several within the overall field of sustainability transitions.[57] Analogous to the goal behind sustainability transitions to shift towards more sustainable modes of production and consumption, the energy transition aims to make the generation and consumption of energy more sustainable. Furthermore, being driven by the development and diffusion of renewable energy technologies, the energy transition becomes a field of action for changes at the level of the socio-technical regime. Seen from the MLP, the concept of energy systems does not differ significantly from the general understanding of socio-technical systems, as the following definition shows.

[55] International Energy Agency 2019, p. 8. Nuclear energy generation has also played a significant role in these CO_2 emission savings.
[56] BP 2019, p. 52; International Energy Agency 2019, p. 4.
[57] Other sustainability transitions occure, for instance, in agriculture and food, water, buildings, and waste management. Köhler et al. 2019, p. 2.

> Energy systems are socio-technical configurations where technologies, institutional arrangements (for example, regulation, norms), social practices and actor constellations (such as user–producer relations and interactions, intermediary organisations, public authorities, etc.) mutually depend on and co-evolve with each other.[58]

Accordingly, the previous figure (**Figure 2**) illustrating the MLP perspective on transitions can be transferred onto the energy transition as well. Building on Geels (2004) and Köhler (2017), **Figure 7** visualises elements in the current and future socio-technical energy regime, including the pressure that social and ecological trends such as changing demographics, increasing urbanisation, aggravating resource depletion and climate change exert on the existing energy regime. The ability of niche actors to react more promptly to these trends than the regime itself causes tensions for the regime, eventually forcing it to open and adapt to the pressure coming from below and above, i.e. from the niche and the landscape.[59] For instance, following an increased demand for localised energy generation, new trajectories may lead away from centralised energy supply by incumbent energy facilities and businesses, moving towards local civil energy cooperatives. Expanding technological capacities for e.g. rooftop photovoltaic (PV) panels support this trend. These new developments exemplify how various activities, represented by miniature arrows pointing in different directions, consolidate and align to one direction.

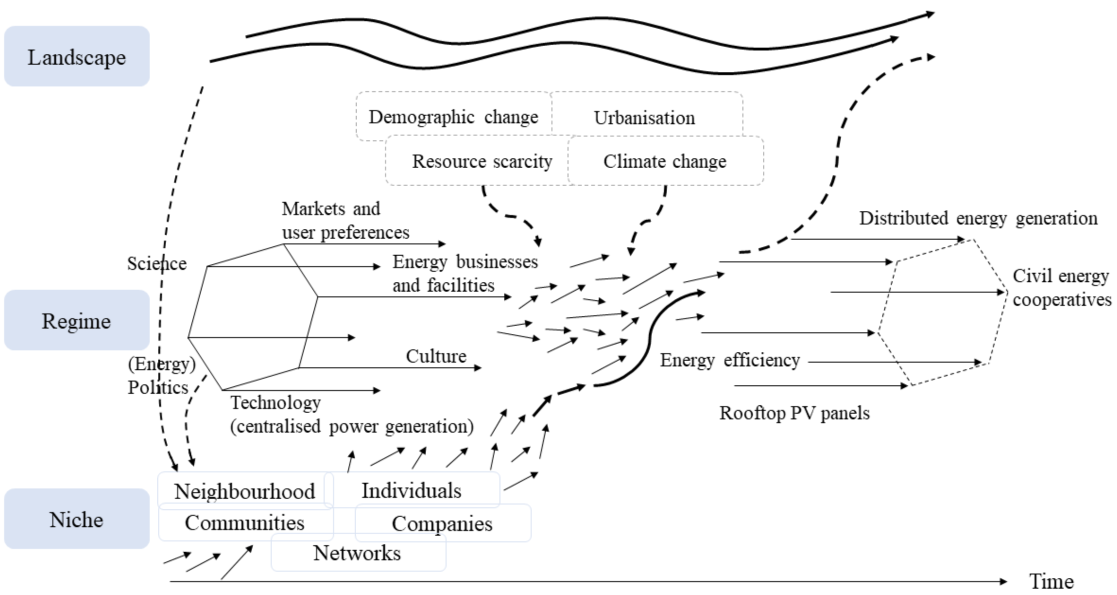

Figure 7 The socio-technical energy system. (Adapted from Geels (2004), p. 401 and Köhler (2017), p. 5)

In Germany, which is referred to as a model country for the energy transition hence observed by countries worldwide, the *energy transition* is defined as a 'replacement of fossil and nuclear

[58] Rohracher and Späth 2014, p. 1417.
[59] Köhler et al. 2017, p. 4.

energy sources with an ecological, sustainable energy supply'[60]. Whereas the goal to transition towards renewable energy is commonly shared, there can be stark country-specific differences in the definitions of *renewable energy*. The British Office of the Deputy Prime Minister defined renewable energy as 'those energy flows that occur naturally and repeatedly in the environment – from the wind, the fall of water, the movement of the oceans, from the sun and also from biomass […] but not energy from mass incineration of domestic waste'[61]. Hence, both the German and British definitions exclude nuclear energy in their understanding of renewable energy sources. The British example explicitly rejects waste incineration, which is not the case in many states in the US, nor does Germany refrain from burning waste and declaring the resulting waste heat as 'recycled'.[62] In China, however, nuclear energy is seen as a green energy source. That explains why China has been expanding its capacities for nuclear energy, which also reflects on the Chinese energy mix.[63] Nonetheless, China has been engaged actively in the national and international energy transition. The underlying reasons for this engagement will be highlighted in the next section.

2.2.2. The energy transition in China

There are multiple motivations for China to transform its national energy system and to become 100 percent renewable, which can be divided into external and domestic. From an external perspective, China has been facing increasing international pressure for being the largest emitter worldwide.[64] **Figure 8** shows that China ranks first, with energy-related CO_2 emissions significantly higher than in the US, which ranks second. In 2017, China attributed 28 percent of total global energy-related CO_2 emissions.[65] CO_2 emissions declined between 2015 and 2016, before increasing to 9.2 Gt in 2017 and 9.4 Gt in 2018, although the IEA (2017) estimates that coal consumption and CO_2 emissions will continue to decline.[66]

The Chinese energy demand growth has correlated with the country's GDP growth, before it saw a decline since 2014.[67] Nonetheless, in 2018, the Chinese energy demand grew by 3.5 percent, amounting to 3155 Mtoe (million tonnes of oil equivalent) and thus reaching a new high since 2012. In sum, China's energy demand constitutes a third of global energy demand growth, while China, India and the US account for roughly 70 percent of global energy demand

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[60] Duden 2019, Energiewende entry; Droege 2006, p. 53; Energy Reform Institute and China National Renewable Energy Centre 2019, p. 3.
[61] ODPM 2004, p. 3.
[62] Donahue 2018.
[63] International Energy Agency 2019, p. 5; Fischer 2018, p. 7.
[64] Aklin and Urpelainen 2018, p. 202.
[65] International Energy Agency 2017b, p. 554 Yet, with per-capita emissions of 6.5t of CO_2, China remains below the average of advanced economies.
[66] International Energy Agency 2017b, p. 476; BP 2019, p. 57.
[67] International Energy Agency 2017b, p. 554.

growth.[68] With the Chinese automobile sector at the forefront of electric vehicle sales, and more and more end-uses being electrified, the domestic energy demand is expected to grow further.[69]

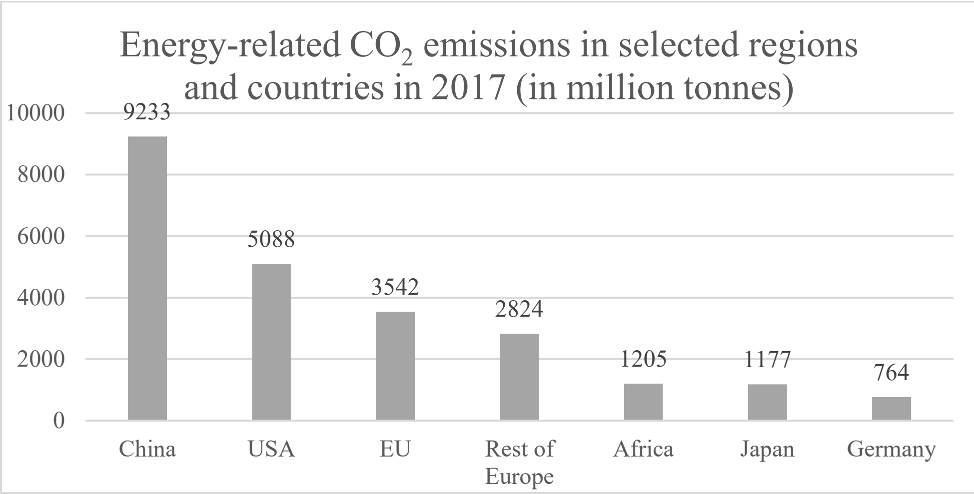

Figure 8 Energy-related CO_2 emissions in selected regions and countries in 2017 (in million tonnes). (Adapted from Statista (2018)

However, rather than by international pressure or the commitment to participate in global efforts for climate change mitigation, Chinese energy policy is primarily driven by the need to solve domestic energy challenges.[70] The increasing energy demand in China has translated into a greater demand for coal, gas and oil, which China has been importing to prevent supply bottlenecks. For instance, in 2018, energy imports amounted to 70.9 percent of the country's oil consumption and 45.3 percent of gas consumption.[71] The resulting dependence on energy imports poses a potential risk to China's national energy security. At the same time, aggravating environmental and health problems, which come with significant economic costs, make it imperative for Chinese energy policy to expand the use of RE.[72] Hence, the Chinese energy sector is turning to RE as a reaction to increased energy demand, endangered energy security and negative health impacts, such as poor air quality.[73]

Indeed, the share of RE in the Chinese energy mix has increased, but it is nonetheless falling short to satisfy the domestic energy demand, and despite the favourable trend for RE, the complete phase-out of coal-fired energy will take China several decades.[74] Besides, China sees a possibility in the energy transition to gain a competitive advantage on the market for RE technologies. By shaping the industry standard for RE technology worldwide, China will be able to avoid additional costs related to acquiring foreign technologies and license fees.[75] Thus, the competition for the innovative edge in RE technologies turns into an incentive for the

[68] International Energy Agency 2019, p. 5.
[69] International Energy Agency 2017b, p. 556; Fischer 2018, p. 7.
[70] Fischer 2018, p. 10.
[71] Energy Reform Institute and China National Renewable Energy Centre 2019, p. 4.
[72] Fischer 2018, p. 6.
[73] Aklin and Urpelainen 2018, p. 201.
[74] Fischer 2018, p. 7; Aklin and Urpelainen 2018, p. 203.
[75] Fischer 2018, p. 8.

Chinese government to actively expand the use of RE domestically. Vice versa, one can argue that the energy transition translates into a business field with significant economic potential.[76]

2.2.3. The role of Renewable Energy Cities

An increasing body of literature related to sustainability transition theory has classified RE projects on the levels of communities, cities and regions as niche projects within the socio-technical energy system. Beginning with the expansion of RE at this level is particularly reasonable since the niche level is where the introduction of RE technologies and related programmes becomes 'most visible and tangible'[77], although ideally, the energy transition is a global concept. Furthermore, three additional characteristics of cities and regions qualify them to be approached with the MLP, which Späth and Rohracher (2012) summarise as follows:

> Cities and regions are often large enough to incorporate at least some of the systemic properties of existing regime structures (typical supply structures, relations of supply and demand, etc.). At the same time, they can be small enough to exploit the advantages of proximity for the creation of new actor networks, discourses and institutions for alternate sociotechnical configurations. Thirdly, they often have well-established governance structures to coordinate change processes (not only city or regional governments, but often also well-organized civil society organizations and networks involved in urban or regional governance).[78]

Generally, *renewable energy cities* (RECs) are defined as cities that exclusively use renewable energy for the supply of electricity, transport, heating and cooling, while emphasising the development of the renewable energy sector.[79] In Chinese early stage energy research, the broader term 'energy city' was rather common. It was used to describe cities which produced large amounts of energy. Only in recent years, research has become more differentiated, and perspectives on transition, low carbon development and environmental protection became prevalent topics in the discussion.[80]

At the same time, 'solar energy cities', 'renewable energy construction pilot cities', 'wind energy cities', 'new energy cities', 'new energy vehicle pilot cities' and 'low carbon cities' appeared in many Chinese regions.[81] As reflected in these diversified project designations, there are broad and narrow understandings of RECs. Apart from the narrow understanding of RECs given in the previous paragraph, there exists a broader understanding as well. According to the broad understanding, 100 percent RECs might not cover all areas of energy consumption, but they can be specialized in either of the three areas or a certain source of renewable energy, such as solar PV. Consequently, this specialisation is reflected on project titles such as '100 percent

[76] Droege 2006, p. 24; International Energy Agency 2017a, p. 12.
[77] Droege 2006, p. 25.
[78] Späth and Rohracher 2012, p. 467.
[79] Lou 2013, p. 30.
[80] Lou 2017, p. 174.
[81] Lou 2013, p. 31.

renewable electricity cities', '100 percent renewable energy construction cities' or '100 percent solar energy cities'. Such specialised REC projects are easier to realise than holistic RECs and thus suitable for any city type, in particular for large Chinese cities.[82] Consequently, the broader understanding of the term is much more commonly used when talking about Chinese RECs. In this thesis, the abbreviation RECs will refer to the narrow understanding, i.e. to projects which target an almost entirely renewable energy mix. Although the abbreviation 'REC' represents only renewable energy *cities*, it will include projects on the level of regions and villages as well.

In China, city-level and regional projects as RECs fulfil a particular role. Although not emphasised in the Five-Year Plans (FYPs) of the central government, the 12th FYP published by the National Energy Agency (NEA) explicitly names RECs, planning to construct 100 RECs, as well as 1000 new energy model regions, with the aim of advancing new energy technologies and standardising their application in cities.[83] In the context of *experimentation under hierarchy*, i.e. as purposefully installed pilot projects, the Chinese RECs serve to pre-test technological innovations and economic or political configurations before selected appropriate experiments are rolled out nationwide. Such experiments result from a hybrid bottom-up and top-down approach, which is distinctive for Chinese policy-making.[84] According to Heilmann (2008), such experiments in China show themselves in three forms, which are 1) *experimental regulation*, in which trial implementation of a new policy is accompanied with provisional rules; 2) *experimental points*, which launch model demonstrations and pilot projects; 3) *experimental zones*, which make room for local jurisdictions that are endowed with 'broad discretionary powers'.[85] In all three categories, the actual hands-on experiments happen at the local level, while the central government filters out appropriate and scalable experiments based on local experiences.[86]

Based on this classification, Chinese RECs correspond to *experimental points*, while also showing striking overlaps with SNM.[87] Seen from an SNM perspective, the installation of *experimental points* equals the provision of protected spaces for innovations, i.e. the intentional creation of niches. Consequently, one can conclude that SNM is a strategic tool for top-down policy-making. With regard to the analysis of such experiments, however, Heilmann (2008) considers the distinction between bottom-up and top-down initiation of policy experiments 'nearly meaningless'. He argues that neither exists in a pure form but rather, the central and local levels are interdependent, i.e. the central government relies on the execution and experiences from the local level, while local governments depend on the central government to

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[82] Lou 2013, pp. 32–33.
[83] Lou 2013, p. 31.
[84] Heilmann 2008a, p. 29 However, 'bottom-up' is not to be mistaken with the grassroots level, but it refers to lower administrative levels.
[85] Heilmann 2008b, p. 5.
[86] Heilmann 2008b, p. 11.
[87] Heilmann 2008b, p. 5.

make room for protected experimentation.[88] Analogously, Chinese RECs should be seen in China as a result of a hybrid evolution from decentralised initiatives and centralised selection. In order to assess the evolution of different niches in the context of SNM and to comprehend drivers behind Chinese RECs while considering the shortcomings of such a dichotomy, this thesis will place niche experiments on a continuum ranging from bottom-up (MLP) to top-down (SNM), as to grasp niches which evolved at the intermediate level as well. This will allow determining if there is an ideal position for RECs on this continuum and what this implies for an ideal niche design.

3. Comparative analysis: the global and the Chinese socio-technical energy systems

Although the MLP has gained wide attention in the literature on sustainability transitions and provided useful heuristics to obtain a structured overview of socio-technical systems, in the case of RECs, little research has adopted the MLP as a framework to concretely analyse the energy sector. Instead, one finds various descriptive articles on selected case studies of regions and communities on their way to energy self-sufficiency, which focus on the niche level detached from the *multi-level* nature of the MLP.[89] Practical applications of this analytical framework can be found in a series of working papers from authors of Fraunhofer Institute for Systems and Innovation Research, who combine descriptive case studies with the MLP.[90] Their method gives guidance for transferring the MLP onto other socio-technical systems as well. Following this approach, this section will first apply the MLP to the global energy system to provide a holistic assessment of the landscape, regime and niche level, drawing on a compilation of international case studies. For this purpose, chapter 3.1 will first assess general drivers on the landscape level. For the regime level (chapter 3.1.2), this thesis will extend Köhler et al.'s (2017) approach by structuring the analysis of RECs along the key elements *culture*, *industry*, *markets and user preferences*, *policy*, *science* and *technology* in correspondence with Geels and Schot's (2007) MLP on transitions. Furthermore, to make existing case studies more comparable, this thesis has developed the four criteria *initiation*, *stakeholder participation*, *government influence* and *function of the niche*. These criteria were developed to comprehend causal directions in niche development, particularly to grasp indicators of SNM. The ultimate goal of this approach is to give an overview of different forms and features of niche development for orientation, before assessing such niches in the Chinese context.

China-specific sustainability transition literature has been suffering from similarly incomplete research. Despite a comprehensive body of literature on the Chinese energy sector and its transition to sustainable energy, research has not yet applied the MLP to the Chinese case.

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[88] Heilmann 2008b, p. 10.
[89] See, for example, Späth and Rohracher 2010, 2012 and Rohracher and Späth 2014.
[90] See, for example, Köhler et al. 2017; Köhler et al. 2018.

Hence, a structured understanding of drivers in the Chinese energy transition is missing. For this reason, chapter 3.2 will analyse the Chinese energy system in an analogous manner. By looking at both the international and the Chinese energy systems, this thesis attempts to grasp driving forces for the Chinese energy transition against the backdrop of an international reference, while the MLP framework allows to capture such forces on both the macro (landscape and regime) and the micro-level (niches) of socio-technical energy systems.

To assess different forms of niche formation, i.e. the evolution of RECs, the analysis of both the global and the Chinese energy systems will conclude with case study analyses. For the international niche level, this thesis will conduct a multi-case report composed of seven European RECs in Graz, Güssing, Feldheim, Freiburg, Helsinki, Jühnde and Murau. The analysis of Chinese RECs will be centred around two case studies in Shaanxi and Tongli. Finally, the results of the case studies will be compared and evaluated in chapter 3.3.

3.1. The global socio-technical energy system

The global socio-technical energy system can be understood as the international energy sector with a focus on the interplay of different elements across the three levels landscape, regime and niche. This international energy system is in turn composed of numerous heterogeneous subsystems, i.e. national and regional energy systems. Following this logic, the international energy system is where overall developments of the energy sector take place, without the ability to capture country-specific characteristics. Yet, the analysis of this general energy system allows to comprehend crucial drivers and challenges for the energy sectors, which will most likely have effects on the country-level as well. To this end, annual reports such as the Special Report of the IPCC by Moomaw et al. (2012), as well as the *World Energy Outlook* and the *Global Energy and CO2 Status Report* published by the International Energy Agency (IEA), which are widely renowned in climate and energy-related academia, will constitute the base of the following analysis. The analysis will correspond to the structure of the MLP, beginning with trends on the landscape level, followed by elements of the global energy regime and finally introducing findings from case studies on RECs.

3.1.1. The international socio-technical energy landscape

The international energy regime faces pressure from various trends on the global socio-technical landscape level. Demographic change, for instance, has implications for energy demand, energy infrastructure and energy capacity by affecting the population size in different regions as well as the number of users.[91] Climate change caused an increased demand for heating and cooling as a result of extreme temperatures in winter and summer. From a macro-economic perspective, global economic stability manifested in a rising energy demand as

[91] Köhler et al. 2017, p. 21.

well.[92] More recently, the US withdrawal from the Paris Agreement in 2017 has gained much attention. Although the exact impacts remain unclear, it is assumed that the US will not only increase domestic emissions, but also affect climate policy in other countries as well.[93] Thus, the far-reaching impacts of the US' withdrawal make it a landscape driver in the international energy system creating pressure on the energy regimes of other countries.

Yet, the intensity of landscape pressure seems to differ across countries. While nuclear incidents such as Chernobyl in 1986 or Fukushima in 2011 resulted in stronger commitment from the German government to phase out nuclear energy, countries including China still classify nuclear energy as a clean and reliable energy source.[94] Thus, this shock on the landscape level had seemingly little influence on the energy mix in the relevant countries.

3.1.2. The international socio-technical energy regime

A major challenge when proceeding to the next level is to assess the socio-technical regime in an appropriate scope. Similar to the overall socio-technical system, regimes vary in size. Along with the development of *subsystems*, regimes can thus be classified into *sub-regimes* based on their technological features or scope. For instance, one can distinguish three sub-regimes within the overall energy system: the electricity regime, the transport regime and the heating regime.[95] A regime analysis can either look at specific energy sources or entire energy markets. Yet, an analysis of regimes at the micro-level which neglects macro-level impacts tends to produce a distorted perception of regime shifts. As Geels and Schot (2007) find, '[w]hat looks like a regime shift at one level may be viewed merely as an incremental change in inputs for a wider regime at another level.'[96] This implies that a country's energy sector can either be seen as a socio-technical system in itself or as a subsystem within the global energy system. However, due to the effects of globalisation on the energy market, the two systems cannot be entirely differentiated. Global trends, such as digitalisation still manifest in landscape elements in the regional energy system as well. Developments in the energy sector may also be overarched by national climate policy, which can in turn be seen as a component of international mitigation efforts against climate change. This explains why Späth and Rohracher (2012) ask for analysing regimes in national or global contexts, although they admit at the same time that regimes vary across nations as well as regionally.[97] For this reason, this thesis will begin with an analysis of the international socio-technical energy regime in order to capture such global developments.

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[92] International Energy Agency 2019, p. 5; 7.
[93] Dai et al. 2018, p. 366 Following the authors' logic, other countries will have to reduce more GHG emissions in order to prevent the global temperature increase from exceeding 2°C.
[94] Central Committee of the Communist Party of China 12/7/2016, p. 84; IAEA 2016, v; Köhler et al. 2017, p. 9; Deutscher Bundestag 2018, p. 2.
[95] Köhler et al. 2017, p. 7.
[96] Geels and Schot 2007, p. 400.
[97] Späth and Rohracher 2012, p. 466.

Based on **Figure 2** by Geels and Schot (2007) shown previously, the socio-technical regime encompasses trajectories from *culture*, *industry*, *markets and user preferences*, *policy*, *science*, and *technology*. These criteria will mark the structure of this regime analysis.

Culture

Researchers have noticed an increased awareness of climate change, which has positive effects on the acceptance towards the energy transition and the adoption of RE.[98] However, numerous intangible factors, which are embedded in the culture and guide human behaviour, represent obstacles for the expansion of RE. Socially entrenched values and norms may manifest in a varying degree of acceptance of RE technologies by local stakeholders. Insufficiently paying attention to stakeholder concerns may in turn evoke resistant behaviour. These concerns are mostly related to the potential impact of RE technologies on their 'behaviour, natural habitats and natural and human heritage sites, including impacts on biodiversity and ecosystems, landscape aesthetics, and water/land use and water/land use rights as well as their availability for competing uses'.[99] The latter constitutes a particular source of conflict. With regard to the installation of wind farms, there is little opposition from the farmers themselves. Wind farms do not interfere with normal agricultural activities but are rather considered as a source of additional income through ownership or leasing contracts. Instead, resistance against wind farms comes from other stakeholders, who advocate for different land uses or consider the installation of RE technologies as a threat.[100] Such land conflicts are not restricted to wind energy but can occur with other RE technologies as well.

Cultural norms and values play a significant role for residents as well. As cultural science research indicates, the individuals' identification with their households determines their activities at home and thus shape households' energy consumption. Hence, energy consumption and energy-saving behaviour is influenced by 'attitudes, social norms and identity'.[101] However, if policy designs fail to address these behavioural aspects appropriately, the individuals' environmental awareness will not translate into action, resulting in 'awareness-behaviour' and 'value-action gaps'.[102] This has negative effects on energy consumption.

Industry

A major obstacle for the expansion of RE are incumbents in the energy sector, such as large energy utilities which dominate the energy market as monopolies. As highlighted by the IPCC special report, monopolies inhibit competition in the energy market and lead to underinvestment in RE technologies due to deficient IP protection for innovators. This implication is relevant

[98] Köhler et al. 2017, p. 8 Yet, the mere awareness of climate change is not enough to instigate a regime shift, but it has to manifest in concrete actions for climate change mitigation first to facilitate sustainability transitions.
[99] Moomaw et al. 2012, p. 195
[100] Moomaw et al. 2012, p. 195.
[101] Andrews-Speed and Ma 2016, p. 25.
[102] Andrews-Speed and Ma 2016, p. 25.

for the Chinese energy regime as well. Particularly in Africa, Asia and the Middle East, the energy sector shows monopolised structures, with one or a few incumbent facilities taking over all major supply functions from power generation to transmission and distribution to customer services. Despite efforts to liberalise energy markets in several countries, current regulations still support centralised generation, transmission and distribution of energy, leaving little room for RE technologies. Hence, due to their dominant role in the energy sector, such monopolies often benefit from favourable energy regulations.[103]

Markets and user preferences

A major trend in the energy regime has been the decentralisation of the energy infrastructure.[104] This trend can be explained by technical characteristics of distributed energy generation which require the dispersed installation of RE plants, allowing energy generation at the point of use, both in urban and rural areas.[105] The expansion of distributed energy generation is further facilitated by decreasing costs of distributed energy technology along with an increasing degree of digitalisation within the energy system.[106]

Economic incentives, however, can substantially impede the expansion of RE. Whereas the need to replace old energy infrastructure potentially opens a *window of opportunity* for new and more energy efficient technologies, high initial investments, switching costs and higher prices for RE result in reluctance to invest in more sustainable electricity or heating, particularly among private households.[107] Existing energy systems in private households are often too old and inefficient to contribute to national GHG reduction targets, but households have little incentive to invest in energetic restoration due to long life-cycles of the installed energy system.[108] Despite increased price competitiveness, up-front costs of RE units exceeding the costs for conventional energy units make them unaffordable for a large part of customers. In fact, initial capital costs account for the major part of the overall costs of an RE system.[109] Levelized costs of energy (LCOE) from RE technologies, which take into account the costs of an energy generation unit over its entire lifecycle, remain higher than for conventional energy as well.[110] This lowers the attractiveness of RE technologies over conventional energy. In addition, from the perspective of individual users, various insecurities affect their willingness to invest in RE installations such as rooftop solar PV panels. These insecurities includes concerns about 'their own economic situation, development of energy prices, access to loans,

[103] Moomaw et al. 2012, p. 194; Moomaw et al. 2012, p. 196.
[104] Köhler et al. 2017, p. 7.
[105] Moomaw et al. 2012, p. 181.
[106] International Energy Agency 2017a, p. 11.
[107] Köhler et al. 2017, p. 8; 21.
[108] Köhler et al. 2017, pp. 9–10.
[109] Moomaw et al. 2012, p. 194.
[110] Moomaw et al. 2012, p. 187 The report admits that LCOE alone do not determine a technology's competitiveness, but they commonly serve as a benchmark, as LCOE roughly indicate the average amount for the technology to breakeven.

limited knowledge of consumption, savings potential or concrete funding opportunities, as well as subjective preferences or prejudices towards certain technologies'.[111]

Policy

Equally vital for the energy transition are policies related to climate change mitigation, such as official measures and targets.[112] These include national policies as well as international commitments. Since the Paris Agreement, for instance, 180 countries have formulated NDCs which, under the overarching goal to reduce GHG emissions, also include ambitions to expand the use of RE.[113] Policies facilitating the expansion of distributed energy are particularly promising, since this form of energy generation is immune to global politics of fuels and resources. Whereas supplying countries rich in fossil fuels may shut down e.g. the supply of gas as a result of political conflicts, distributed energy systems (DES), allowing for generation and consumption of RE on-site, reduce the reliance on international fuel suppliers. They are thus invulnerable to this kind of political and energy-related destabilisation.[114]

Nevertheless, unfavourable policy elements can pose a significant obstacle for the expansion of RE. For instance, so-called "hard institutions"[115] include inappropriate or lacking standards and regulations which disincentivise behaviour and actions in line with the energy transition. Apart from the lack of appropriate policy programmes, over-regulation is also an example of a discouraging policy. As a result, such regulations and standards impede the development of regime deviations. For instance, overly demanding regulations can impede the profitability of businesses which struggle to conform. Apart from hard institutions, their counterpart "soft institutions"[116], which include relationships between key stakeholders, can be a source of conflict as well. For examples, disputes between project teams, residents and banks may lower acceptance towards the energy transition, potentially hampering the development of the niche. Furthermore, public institutions tend to believe that shifting away from fossil fuels is accompanied by immense economic and transactional costs. In fact, however, high fossil fuel prices cause higher welfare losses than effective climate policies.[117] Due to their dominant role in the energy sector, regulations for energy businesses are often centred around energy monopolies. Finally, as mentioned in criterion *Industry*, existing regulations continue to support centralised generation, transmission and distribution of energy in many countries.[118] This circumstance reinforces the dominance of energy monopolies.

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[111] Köhler et al. 2017, p. 10.
[112] Köhler et al. 2017, p. 7.
[113] Energy Reform Institute and China National Renewable Energy Centre 2019, p. 2; International Renewable Energy Agency.
[114] Droege 2006, p. 89.
[115] Köhler et al. 2018, p. 16.
[116] Köhler et al. 2018, p. 17.
[117] Moomaw et al. 2012, p. 195; Vielle and Viguier 2007, p. 844.
[118] Moomaw et al. 2012, p. 196.

Science

Science on RE technologies is hampered by lack of data, such as the output of natural resources in combination with topographic conditions. For instance, the energy output of wind turbines varies depending on local topography. Obtaining this type of data, however, is connected to significant measurement and modelling efforts, which may overwhelm smaller communities.[119] In addition, skills shortage, i.e. the lack of trained human resources inhibits research and development in the field of RE technologies in two ways. On the one hand, versatile expertise in areas such as mechanics, chemistry, and engineering but also in business management and social sciences is vital for the development of RE technologies. On the other hand, dispersed RE systems require skilled technical support on-site, particularly in remote or underdeveloped areas. The deployment of RE must hence be accompanied by training for experts and local stakeholders.[120] Yet, technological innovation related to RE suffers from deficient IP protection, impeding RE research as well. Although improved IP protection through patents can incentivise innovators and help attract more private R&D investment, related access costs for these technologies may discriminate against developing countries which are in need of such RE technologies.[121]

Technology

RE technologies have specialised along the different energy sources, which can be seen as both strength and weakness. On the one hand, these different energy systems have contributed significantly to urban development and the diversity of RE systems offers RECs a flexible set of RE technologies matching context-specific requirements. The megatrend of digitalisation in particular, previously identified as a landscape driver, opens possibilities for smart energy supply through smart metering with the potential to increase energy efficiency.[122]

On the other hand, the afore-mentioned specialisation of RE technology is accompanied by increasing complexity. In addition, once established, existing energy supply systems are difficult to alter.[123] Furthermore, despite the afore-mentioned efficiency gains, digitalisation also consumes an increasing amount of energy through data transmission and connected devices. In 2017, the share such data centres and networks in global electricity demand was roughly 2 percent and is yet to increase. Hence, energy efficiency improvements are needed in the IT sector as well.[124]

[119] Moomaw et al. 2012, p. 194.
[120] Moomaw et al. 2012, p. 195.
[121] Moomaw et al. 2012, p. 196.
[122] International Energy Agency 2017b, p. 58.
[123] Droege 2006, p. 107 See also Droege's renewable energy toolbox, a collection of viable technologies for different RE sources.
[124] International Energy Agency 2017b, p. 58.

Another major advantage of RE is that RE technologies are compatible with any electricity system, ranging from large grids with continental scope to small networks in energy autonomous buildings.[125] The volatility of RE sources, however, remains a crucial challenge.[126] To cushion peaks, for instance in times of solar energy surplus or supply bottlenecks in windless hours, development of battery storage is crucial. Yet, the price for battery storage is high, and large-scale deployment in utilities has only begun, which means that economies of scale are yet to be awaited. [127] Generally, technology development suffers from under-investment, presumably because the development of RE technology primarily addresses the public sector, which reduces incentives for actors in the private sector to invest in the RE industry.[128]

This section has provided an overview of key elements in the international energy regime, which are summarised in **Table 1**. However, it should be noted that due to the limited scope of this thesis, only major trends were highlighted in this section, mainly derived from the afore-mentioned reference literature. Nevertheless, this section was able to show that the MLP approach potentially allows for a comprehensive overview of key regime elements reflecting the status quo of the global energy sector, although this would require an extensive literature review and time resources.

Table 1 Overview of elements in the international energy regime. (Own table)

Culture	Industry	Markets and user preferences	Policy	Science	Technology
• Increased public awareness • Values and norms • Acceptance *vs* conflicts	• Incumbent utilities • Economies of scales • Decentralisation • Liberalisa-tion	• Economic incentives • Up-front and switching costs • Higher RE prices • High LCOE • User insecurities	• NDCs • National reduction targets • Hard and soft institutions • Monopoly-centred	• Lack of data • Skills shortage • Under-investment • Inappropriate IP laws • Limited benefits for innovators	• Efficiency gains • Compati-bility of RE • Smart energy • Long life-cycles

[125] Moomaw et al. 2012, p. 184.
[126] Moomaw et al. 2012, p. 196.
[127] International Energy Agency 2017b, p. 60.
[128] Moomaw et al. 2012, p. 196.

3.1.3. Niches in the international socio-technical energy system

Worldwide, there are numerous cities, communities and regions which are either on their way to become 100 percent renewable or have already achieved this goal. International organisations and initiatives have published lists of 100 percent RE cities and communities, such as the *Ready for 100* campaign by Sierra Club, an environmental organisation in the US, the global platform Global 100% RE and the Carbon Disclosure Project.[129] Other international initiatives are *E-C Energie-Cités* in Europe, the *Green Cities programme*, and the *Cities for Climate Protection* campaign by the International Council for Local Environmental Initiatives (ICLEI).[130] Apart from these international, mostly voluntary initiatives, many academic articles have dealt in-depth with the design and the implementation of various RECs as well.

This section will compile a multi-case report on seven international case studies, drawing upon single case studies on Graz, Freiburg and Murau (Späth and Rohracher 2010; 2012 and Rohracher and Späth 2014), on Feldheim (Kunze and Busch 2011; Busch and McCormick 2014) as well as on Güssing, Helsinki, Jühnde and Mureck (Radzi 2012). **Table 2** gives an overview of the selected cases and the type of their REC. Noticeably, the location of the selected cases is concentrated on European countries with a predominant representation of RECs in Germany and Austria. Nevertheless, the selection is not based on the RECs' location but rather on the availability of comprehensive documentation. The case studies by Radzi (2012), Kunze and Busch (2011) and Busch and McCormick (2014) cover detailed records on the evolution and implementation processes of RECs, while Späth and Rohracher (2010; 2012) and Rohracher and Späth (2014) employed specific aspects of the MLP. The selected case studies in this thesis have already been completed, which allows assessing their developments in light of their results. Originally, Radzi's (2012) case studies covered 14 RECs in total. However, to maintain comparability across the cases, this multi-case report excludes energy autonomous islands and larger regions and focuses on cities and villages instead. With sufficient similarities to be comparable and sufficient differences to complement each other, this sample attempts to represent a compilation of varying niche formation processes.

The multi-case report will begin by describing the *initiation* of the afore-mentioned cases in order to determine whether the niches evolved by strategic selection or local initiatives. This criterion also aims at comprehending motivations driving governments to promote RECs in the context of SNM. To assess to what extent stronger stakeholder participation is congruent with independent niche development, this thesis will proceed with the criterion *stakeholder participation*. Based on the assumption that stronger government interference means that SNM was employed, the analysis will apply the criterion *government involvement* in the next step. Yet, integrating Heilmann's (2008) criticism towards an overly sharp distinction between bottom-up and top-down, the analysis will consider the relationship between MLP and SNM as

[129] Sierra Club 2016; Global 100% RE 2016.
[130] Droege 2006, p. 119.

a continuum and determine the position of the respective RECs on it. A fourth criterion, the *function of the niche*, will compare the niche developments with the four-phase model proposed by Geels (2004) (see chapter 2.1.3), which will allow at the same time to determine influences of SNM on the niche development. Subsequently, the report will summarise the findings and conclude with an analysis of the different dynamics behind niche development.

Table 2 Overview of selected cases and projects. (Own table)

Case	Project
Graz, Austria	Eco-city aiming to reduce GHG emissions by 50 percent, replacing fossil fuels with solar thermal energy and energy contracting models for the investment in energy efficiency
Güssing, Austria	*Güssing model* for phasing out fossil fuels, reducing energy consumption and supplying the town with biomass and solar energy
Feldheim, Germany	First German energy self-sufficient village, relying on biomass, wind energy and solar energy
Freiburg, Germany	*Energy Supply Concept* for reducing energy consumption, increasing the share of RE and phasing out nuclear energy
Helsinki, Finland	*Eco-Viikki*, Finland's first ecological residential area, relying on solar energy
Jühnde, Germany	*Bioenergy Village*, completely relying on biomass for electricity and heating
Murau, Austria	*Energy Region*, self-sufficient electricity and heating based on bioenergy

Initiation

The initiation of the RECs varies greatly. Whereas some were initiated top-down by government ministries, others emerged on the initiative of local stakeholders. A top-down example is the construction of *Eco-Viikki*, a Finnish experimentation area for environment-friendly housing, which was initiated by the Ministry of Environment in cooperation with the Finnish Association of Architects (SAFA).[131] In the case of Graz, the impulse came bottom-up from engaged local residents, who were active in local politics and established relations with the municipal administration, as well as with energy experts in both the city administration and the technical university. Before its efforts to become renewable, the city had been plagued by bad air quality, a landscape element which pressured the socio-technical regime of Graz.[132] In

[131] Radzi 2012, p. 146.
[132] Rohracher and Späth 2014, p. 1420.

Freiburg, the bottom-up nature of the local energy transition is even more pronounced, coming from civil protests against coal-fired and nuclear energy.[133]

Nevertheless, driving forces behind RECs cannot always be distinguished as either top-down or bottom-up. Rather, RECs may emerge in between or outside this continuum as well. For instance, the transition towards energy self-sufficiency in Feldheim began with the installation of wind turbines in 1994, subsequently involved additional RE technologies such as solar PV and biomass energy, until it resulted in an interconnected energy system of households and the energy grid.[134] Because it was the local company 'Energiequelle' that had approached the municipality with the request to install wind turbines, this form of initiation can neither be classified as bottom-up nor top-down, but it should be understood as a hybrid form.[135] Similarly, the local transition in Güssing emerged at an intermediate level between bottom-up and top-down, as the decision to transition towards RE was made jointly by the mayor, the town's electrical engineer, and the head of the local timber growers association.[136] In Murau, a heterogeneous team composed of the head of the local energy agency, a professional facilitator of participatory processes and a group of energy activists initiated the local transformation into an *Energy Region*.[137] Local energy transition can also be induced by research institutes, such as the *Bioenergy Village* in Jühnde, which was initiated by the Interdisciplinary Centre for Sustainable Development (IZNE) in 1998 on behalf of the universities in Göttingen and Kassel.[138]

However, analysing the extent to which such niches are instigated bottom-up, top-down or at an intermediate level does not yet suffice to determine if they develop instinctively or in the context of SNM. Therefore, the next two criteria will highlight niche designs with regard to *stakeholder participation* and *government influence* in order to assess whether these niches are being steered actively.

Stakeholder participation

The designated role of stakeholders in the design of niches is equally diverse. Local stakeholders play a crucial role for the niche development, as the case of Helsinki shows. *Eco-Viikki* presumably missed its energy and heat consumption targets because technical knowledge was not transferred onto local actors, which impeded the appropriate maintenance of the deployed technologies and led to inefficiencies.[139] Instead, the seminars and workshops that *Eco-Viikki* held were primarily targeted at building experts.[140] The pilot project would have

[133] Rohracher and Späth 2014, p. 1422.
[134] Kunze and Busch 2011, p. 12.
[135] Busch and McCormick 2014, p. 7.
[136] Radzi 2012, p. 108.
[137] Späth and Rohracher 2010, p. 452.
[138] Radzi 2012, p. 117.
[139] Nieminen 2018.
[140] City of Helsinki and Ministry of the Environment 2005, p. 48.

allowed for a significant potential of user experiences to improve the integration of RE technologies in the residential area. However, this potential had remained untapped, although residents were eager to contribute to a more sustainable environment.[141] Yet, the original concept of *Eco-Viikki* allowed residents room to shape the eco-community to a certain extent. For instance, resident groups composed of three to five families could apply for a bidding competition with their concepts of 'self-build projects', given that the groups were represented by at least one building expert. In addition, the construction of *Eco-Viikki* was accompanied with numerous blank spaces, which residents filled subsequently with self-managed gardens.[142] As result of incomplete stakeholder management, overall feedback by residents was mixed, ranging from 'This is really a wonderful home for someone such as me' to 'A nice place, badly built'.[143]

In Murau, stakeholder participation played a more important role already in the concept. The *Energy Region* began with a workshop, in which 30 participants from local energy organisations brainstormed on the regional status quo and the desired future. During moderated discussions, participants could openly voice concerns and suggestions. Also, all of them participated in selecting priorities, which were then consolidated in the common vision of an energy autonomous Murau.[144] Workshops proved to be a common method to increase stakeholder acceptance and to transfer knowledge. In Jühnde, workshops aimed at educating village groups and empowering them to become *prosumers*, i.e. users who both generate and consume energy, through active participation in the production of bioenergy.[145] Besides, stakeholders were invited to participate in village meetings and roundtables, planning workshops and working groups. In addition, social activities were organised, such as festivals and contests for painting and running. Along with increased income, new employment and the dissemination of knowledge, sound stakeholder management had a positive impact on villagers' satisfaction.[146]

In Güssing, stakeholders have assumed indispensable responsibilities. For more than 15 years, local farmers supplied residents with biomass energy and to date local heat networks are operated by inhabitants.[147] To institutionalise knowledge dissemination, a *Solar School* was founded which offers training for professionals and students alike. Altogether, community involvement was one of the crucial pillars for the successful transition of Güssing.[148]

The case of Feldheim demonstrates a particularly intensive form of stakeholder participation. As Vattenfall, the provincial grid-monopolist, denied providing grid infrastructure for the village's wind turbines, Feldheim decided to construct a new and independent grid. Connecting

[141] Nieminen 2018.
[142] City of Helsinki and Ministry of the Environment 2005, p. 35.
[143] City of Helsinki and Ministry of the Environment 2005, p. 1.
[144] Späth and Rohracher 2010, p. 452.
[145] Radzi 2012, p. 118.
[146] Brohmann et al. 2006, p. 15.
[147] Europäisches Zentrum für Erneuerbare Energien Güssing.
[148] Radzi 2012, p. 110.

to the new grid required households to invest a lump sum of 1,500 EUR in exchange for an energy price guarantee for the following ten years.[149] At the same time, Energiequelle offered shared ownership to local stakeholders for its energy installations.[150] During the project implementation, diverse expert groups composed of local stakeholders assumed the responsibility for specific aspects. Based on their skills, this form of labour division further contributed to knowledge dissemination.[151] In addition, stakeholder management in Feldheim was not limited to stakeholder participation in energy installations. Energiequelle also engaged actively in social life, sponsoring village fairs and maintaining streets and side-walks, as well as technical equipment for the local football pitch. Furthermore, the company created jobs, ensured reliable energy prices, supported social life and contributed to climate change mitigation. Altogether, the company's efforts to support residents' social life in Feldheim improved 'social cohesion' and strengthened 'local identity' in the community.[152]

Government influence

Government entities participating in the niche development of the afore-mentioned cases were mainly municipal bodies. For instance, the municipal council of Freiburg reacted to local protests by designing an 'energy supply concept' to save energy and increase the share of RE, while phasing out nuclear energy completely. Throughout the further development, the municipality of Freiburg contributed actively to promoting energy-saving technologies for heating and power. Besides, it imposed standards concerning insulation and energy-efficient buildings, which proved to be particularly effective.[153]

The project in Güssing was partly financed by the Austrian government and the local government of Burgenland, and in addition the project could mobilise EU funds. Apart from financial support, there was no other significant contribution from the regime level.[154] In Jühnde, the role of government bodies was limited to funding as well. For Jühnde's *Bioenergy Village*, the major share of funds was contributed by the former German Ministry of Food Agriculture and Consumer Protection (BMELV) and the German Agency of Renewable Resources (FNR), while state and municipal governments sponsored the rest. The responsibility of the municipal and district councils in Jühnde was to supervise the planning process, along with representatives from clubs and associations, the church, university groups and other planning groups. Hence, government bodies did not play a dominant role for the niche development in Jühnde.[155]

[149] Kunze and Busch 2011, p. 11.
[150] Busch and McCormick 2014, pp. 8–9.
[151] Busch and McCormick 2014, p. 13.
[152] Busch and McCormick 2014, p. 8; Busch and McCormick 2014, p. 9.
[153] Rohracher and Späth 2014, pp. 1422–1423.
[154] Radzi 2012, p. 109.
[155] Radzi 2012, p. 118.

There were two cases in which the central government interfered. In Feldheim, the lack of laws regulating ownership structures for Feldheim's independent energy grid forced the German Federal Government to take actions and to establish an appropriate legal framework.[156] This case exemplifies at the same time, how niche dynamics can enforce changes on the regime level. Selected by the Finnish Ministry of Environment and SAFA, *Eco-Viikki* was established in the context of the Climate Change Conference in Rio and the Kyoto Agreement. It is thus connected to international efforts to mitigate climate change. Reacting to the government's demand for this ecological experimentation area, *Eco-Viikki* was predominantly initiated and developed by the City of Helsinki. The project concept already conceived the sole installation of solar energy, which was possible since all buildings were yet to be constructed.[157] Throughout the development of the experimental area, the municipality relied on funding by the Finnish Ministry of Environment and the National Technology Agency of Finland (Tekes), a governmental funding agency.[158] The Finnish government's strong involvement in the project is further demonstrated by the fact that it possessed one third of the available plot area for *Eco-Viiki*. Hence, prior to the construction of buildings, the municipality had to negotiate with the state. The State Real Property Institute then sold the plots to the building developers.[159] According to Radzi (2012), the government's motive to own land plots in Eco-Viikki was to 'maintain control over development and promote environmental quality'.[160] Altogether, the evolution of *Eco-Viikki* strongly leads to the conclusion that the experiment had been established in the context of SNM.

In all of the afore-mentioned examples, local government bodies have provided crucial support for the niche development. However, government influence can also have negative effects. In the cases of Graz and Freiburg, institutions, policies, interests on and actors on various administrative levels proved to be obstacles to niche dynamics.[161] The niche development in Graz suffered from the introduction of partial privatisation of energy utilities, which diminished the active influence of the municipality on the city's energy system, and the circumstance that key actors in the city administration left due to a financial scandal. The city administration of Freiburg faced strong resistance from provincial authorities with regard to expanding installed capacities of RE.[162] In Güssing, legal problems related to EU funding, which occurred during the implementation phase, had severe impacts on the project progress.[163] These examples illustrate at the same time how institutions from the regime level, i.e. elements related to *policy*, can challenge the niche development.

[156] Busch and McCormick 2014, p. 9.
[157] Radzi 2012, p. 147-148.
[158] City of Helsinki and Ministry of the Environment 2005, p. 7; Research and Innovation Observatory 2019.
[159] City of Helsinki and Ministry of the Environment 2005, p. 14.
[160] Radzi 2012, p. 149.
[161] Rohracher and Späth 2014, p. 1425.
[162] Rohracher and Späth 2014, p. 1421; 1423.
[163] Radzi 2012, p. 109.

Function of the niche

To determine which role the niches played in the broader context of the MLP, one can refer to Geels' (2004) description of the four phases in niche development as outlined in chapter 2.1.3. In the first phase, a technological innovation emerges to solve a local problem. This can be observed in Güssing, where increasing fuel debts resulting from a strong dependence on fuel imports had forced the municipality to transition towards RE.[164] In Graz, poor air quality on the landscape level had mobilised residents in the local niche to advocate RE, putting pressure on the existing socio-technical regime. To a more extreme extent, the city of Freiburg turned to RE after engaged inhabitants of Freiburg rose up against the planned construction of a nuclear energy plant nearby in the mid-1970s. These two cases show that stakeholder groups such as experts or environmental activists, as well as actor networks connected to the local administration can build up significant momentum for change on the niche level.[165]

At the core of the second phase is the formation of niche communities composed of experts and other relevant stakeholders, which jointly contribute to further improvements of the innovation. Such niche communities were found in several case studies as well. In Freiburg, for instance, individuals from different organisations, such as research institutes, lobbies or businesses contributed ideas for an alternative energy system. In addition, Freiburg's population had many well-informed citizens, who expressed their thoughts in letters and petitions.[166] A similar network was built in Graz, where engaged residents proactively connected with stakeholders in local politics, the city administration and the technical university.[167] Murau *Energy Region* already enshrined the strategic establishment of such a niche community in the project concept, which was supposed to represent stakeholders from different backgrounds. Yet, the initial niche community was able to initiate a snowball effect, motivating more stakeholders to participate in the niche development. Subsequently, various subgroups focused on specific targets and strategies to become 100 percent renewable, facilitated by the fact that citizens in Murau were well-connected to other relevant stakeholders or businesses.[168] The Güssing model institutionalised such a niche community by a *European Centre for Renewable Energy* (EEE) to facilitate the transfer of knowledge and technologies. In the EEE, a 'team of highly trained technicians and international scientists' gathers to engage in further research on RE.[169] As highlighted previously, the implementation of Feldheim's path towards energy self-sufficiency relied largely on the participation of expert groups as well, which cooperated with other stakeholders to share skills and knowledge.[170] A similar form of niche community can be found in Jühnde's working groups for the local *Bioenergy Village*, in which 22 percent of house

[164] Radzi 2012, pp. 107–108.
[165] Rohracher and Späth 2014, p. 1420-1425.
[166] Rohracher and Späth 2014, p. 1424.
[167] Rohracher and Späth 2014, p. 1420.
[168] Späth and Rohracher 2010, p. 452-453.
[169] Radzi 2012, p. 110.
[170] Busch and McCormick 2014, p. 13.

owners were willing to engage to support the implementation.[171] The only case which does not apply to this phase was *Eco-Viiki*, which refrained from involving residents in the niche development despite their significant potential for feedback.

In the third phase, the innovation improves in terms of price-performance ratio and compatibility with existing structures as to enhance its competitiveness. Since most cases received funding or subsidies, the projects did not have to engage in such improvements. Rather, costs were reduced externally through financial support. Though not constituting an improvement of cost effectiveness and compatibility in the original sense, the population of Jühnde ensured that the generation of bioenergy matched local price structures. Costs of energy generation were consequently adapted to price levels of conventional energy generation, while preventing income losses for local farmers at the same time.[172] In Güssing, the transition towards RE itself embodied an improved price performance ratio, given that the town had been struggling with amassing debts for fuel imports. Through energy saving measures and a ban on fossil fuel usage in public buildings alone, Güssing was able to cut energy expenditures by 50 percent within two years. The construction of a biomass gasification power plant further reduced energy costs for local consumers, with feed-in tariffs cushioning the high costs for biomass feedstock.[173]

Interestingly, the case of Feldheim stands out not because it achieved economic and technological improvements, but because it developed parallel structures which cannot be assessed with the perspective of price-performance improvements and technical compatibility. Relying on an independent grid, self-sufficient Feldheim does not need to enhance the competitiveness of the deployed RE technologies at all. However, another feature of the third phase is the emergence of imitators or competitors attempting to copy the innovation, which applies to some of the RECs. Building upon its experiences as an Energy Region, the project developers from Murau were involved in the establishment of other RECs in Austria and engaged in knowledge dissemination internationally.[174] Furthermore, the successful transition towards self-sufficiency in Jühnde spilled over onto 30 villages in the region, which aspire to become self-sufficient as well.[175] In addition, Graz, Freiburg, Murau were awarded national and international prizes, which makes them potential role models for other RECs as well.[176]

Nevertheless, due to a lack of relevant observations in the original case studies, it remains unclear if there were further improvements in terms of technological price-performance ratio. Hence, future research may attempt to comprehend which effects the introduction of RE had on local economic structures and in how far costs related to RE were improved.

[171] Brohmann et al. 2006, p. 14.
[172] Radzi 2012, p. 119.
[173] Radzi 2012, p. 108.
[174] Späth and Rohracher 2012, p. 472.
[175] Radzi 2012, p. 120.
[176] Späth and Rohracher 2010, p. 455; Rohracher and Späth 2014, p. 1425.

The fourth phase describes the complete replacement of the dominant technology by the innovation, which applies to Güssing, Feldheim, Helsinki and Jühnde. In Feldheim, the niche development began with the installation of a few wind turbines and expanded through the integration of solar and biomass energy. Forced to construct an independent grid, Feldheim ultimately became energy self-sufficient. Whereas Güssing successively expanded the share of RE in the local energy mix to halt its dependence on fuel imports, *Eco-Viiki* in Helsinki was designed as 100 percent renewable from the beginning, with solar energy supposed to cover the energy demand of the residents. The *Bioenergy Village* in Jühnde was originally established to explore the potentials of bioenergy, where it could build upon favourable conditions since a) there were abundant biomass resources and b) the major part of households was already connected to the grid. By installing a biomass and a biogas plant, the transition towards 100 percent RE was completed. With the exception of slacks in the availability of RE sources, hydro, wind, solar and biomass energy were able to make Murau energy self-sufficient as well.[177]

The only two cases which did not complete the fourth phase are Graz and Freiburg. This is most likely because these two cases constitute larger cities, as opposed to the other cases, where the transition to RE took place at a village or community level. According to media reports, energy self-sufficiency is piloted the first time in a district of Graz, indicating that Graz as a city cannot yet rely on RE completely.[178] Freiburg intends to become energy self-sufficient under the overarching goal to become climate neutral by 2050.[179] **Table 3** provides an overview of the European sample in view of completed niche development phases. However, as before, a comprehensive analysis would require continuous observations on the technological structures in each case to evaluate if dominant technological configurations had been completely replaced by RE.

Table 3 Niche development phases in the selected cases. (Own table)

	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Graz	X	X		
Güssing	X	X	X	X
Feldheim	X	X	n.a.	X
Freiburg	X	X		
Helsinki				X
Jühnde		X	X	X
Murau		X		X

Yet, opinions on the question whether all afore-mentioned RECs constitute niche experiments diverge. Instead of instigating broader system transitions, some cases may have been designed to prove the mere feasibility of certain technologies and indicate possibilities to integrate them

[177] Österreichischer Rundfunk 5/9/2019.
[178] Die Presse 2/26/2019.
[179] Freiburg Wirtschaft Touristik und Messe 2016, p. 7.

into alternative configurations. Nevertheless, they may play important roles for preparing future transitions. Murau *Energy Region*, for example, did not primarily serve as a protected space for the development and maturation of technological innovation, but rather aimed at improving frameworks to better incorporate existing technologies to facilitate their expansion.[180] Similarly, the *Bioenergy Village* in Jühnde was initiated to explore capacities of bioenergy, with a focus on technical feasibility of the technology as well.

In addition, the REC initiatives in Freiburg and Graz have shown to diverge from the traditional 'niche-regime dichotomy' for similar reasons. Firstly, neither of the two cities created protected space for technological experimentation, thus they did not engage in niche formation in the stricter sense. Secondly, the socio-technical regimes of Freiburg and Graz did not necessarily come up with completely new configurations, but rather merged with elements from the old system, i.e. not all elements were replaced and energy systems involving different energy sources coexist. Thirdly, resulting configurations of these eco-cities were designed to be copied by other municipalities instead of entering the regime level to induce a broader shift on that eventually permeating the entire socio-technical system.[181]

However, this thesis argues that the previous arguments do not necessarily contradict the logic of niche development. By attracting a growing number of imitators, as it was the case in Graz, Freiburg, Jühnde and Murau, RECs can gradually increase their momentum and create multiplier effects as well. Not least because Graz, Freiburg and Jühnde received awards for their efforts, such RECs can gain recognition from actors and institutions on the regime level, which may enable their model to enter the regime. This argument is further supported by Späth and Rohracher (2012), who admit that these RECs provide fruitful ground for innovations with the potential to pave the way for more radical innovations.[182]

The selected sample of RECs delivers a set of different niche features in RECs. With the methodological groundwork for the assessment of socio-technical energy systems and first insights from case studies, section 3.2 will proceed with the evaluation of the Chinese counterpart, before comparing the results of the two analyses in section 3.3. to explore if and how RECs evolve differently in the Chinese socio-technical energy system.

3.2. China's socio-technical energy system

Having assessed current dynamics in the international energy system throughout chapter 3.1, this section will proceed with the Chinese energy system. As discussed above, the MLP can be used to look at the Chinese energy sector in two ways, either as an individual socio-technical energy system or as a sub-system within the global energy system. Since the overarching global energy system has already been assessed, the Chinese energy system will be treated as an

[180] Späth and Rohracher 2012, p. 475.
[181] Rohracher and Späth 2014, p. 1426.
[182] Späth and Rohracher 2012, p. 476.

individual entity upon which the MLP will be applied. Hereby, this thesis attempts to a) figure out with which similarities and differences the Chinese energy system is embedded in the global system and b) why and in how far the role of the niche in China differs from the original niche understanding. Following the previous structure, this chapter will first investigate to what extent dynamics in the global socio-technical energy landscape can be found on the Chinese landscape before comparing elements in the global socio-technical regime with its Chinese counterpart. The analysis of the niche level will be based on two case studies of 100 percent renewable community projects in Tongli New Energy Town (TNET) in Jiangsu province and the *Sunflower Project* in Shaanxi province to assess the function of such RE pilot projects. Finally, the results of the comparative analysis will be presented in section 3.3.

3.2.1. China's socio-technical energy landscape

The Chinese socio-technical energy landscape faces similar pressure to the rest of the international community. The key trend in the Chinese landscape is continued urbanisation. With an urbanisation rate of 56.1 percent in 2015, which is estimated to increase to 63 percent in 2020, urbanisation poses a significant challenge to the nation, as more than one billion people are expected to live in Chinese cities by 2020.[183] The anticipated urban agglomeration will confront the Chinese energy infrastructure with higher capacity requirements in both urban and rural areas, having to provide enough energy for densely populated metropoles, while ensuring energy access in sparsely populated and remote areas at the same time. A different narrative on China's development in the energy sector purports that the country's rapid economic development was able to lift a substantial part of the population out of (energy) poverty, which resulted in a surging demand for energy sources as well. This was particularly relevant for fossil-fuels, since the country's fast economic and industrial development preliminarily was built on coal.[184] A common ground in both narratives is the fact that energy consumption per capita in China has grown parallel to the urbanisation rate.[185] However, economic and demographic trends are unevenly spread across provinces and regions and concentrated in the eastern provinces, which account for 35 percent of the Chinese population. Consequently, the major share of the domestic energy demand comes from the industrial coastal provinces Shandong, Hebei and Jiangsu in the East of China.[186] Similar to the global energy landscape, progressive digitalisation has manifested in a higher energy demand in China. This trend is closely connected to an increasing electrification of end-uses. By raising the energy demand, this development will reflect on CO_2 emissions as well.[187]

[183] Deutsche Energie-Agentur 2018a; Long et al. 2018, p. 93.
[184] International Energy Agency 2017b, p. 472.
[185] Long et al. 2018, p. 93.
[186] International Energy Agency 2017b, p. 482.
[187] International Energy Agency 2017b, p. 556.

Resource scarcity is another crucial driver of energy policy. In China, coal shortage has a particularly strong effect on the energy sector. Consequently, the Chinese government had to close coal-fired power plants in 2008, giving impetus to the promotion of wind energy instead. Along with a sustained growth in energy demand, China has been struggling with a significant dependence on coal, gas and oil imports (see chapter 2.2.2). Having evolved over a long period of time, this dependence cannot be seen as a mere regime element. Rather, it has been recognised as both an industrial and political risk, which exerts substantial pressure on the Chinese energy regime.[188] The expansion of RE technologies in China promises to curb this dependence on energy imports.[189] Yet, China remains a major player also on the global fossil fuel market with a share of nearly 50 percent in global coal production and consumption. In addition, China has assumed a leading position in global oil imports and an increasing role in global gas markets.[190] Although the Chinese energy industry saw progress in decreasing its reliance on coal, carbon emissions in China nevertheless increased due to increased energy demand from the secondary industry, another driver on the landscape level.[191]

Simultaneously, the Chinese energy mix must become cleaner. The current energy consumption pattern has resulted in severe environmental and climate problems such as deteriorated air quality, which affect the health of the Chinese population and have manifested in significant economic costs.[192] Yet, the domestic energy demand is set to rise, resulting from a combination of different factors. A faster growth of electricity demand 'due to the improved economy'[193] has been identified as one factor. Pressure on China comes also from the international community of states, who expect the largest CO_2 emitter worldwide to comply with its NDCs formulated after the COP21.[194] The US withdrawal from the Paris Agreement affects the Chinese energy landscape as well. Yet, China may be able to benefit from this, taking the lead in the development of clean energies.[195]

All these developments exemplify how landscape trends become powerful drivers, pressuring the regime to embrace RE. While certain regime elements facilitate the expansion of RE, other elements still pose obstacles for the country's energy transition. These elements will be described in the next section.

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188 Fell 2012, p. 61; Fischer 2018, p. 6.
189 Fischer 2018, p. 7.
190 International Energy Agency 2017b, p. 471.
191 Energy Reform Institute and China National Renewable Energy Centre 2019, p. 8.
192 International Energy Agency 2017b, p. 554; Fischer 2018, p. 6.
193 Energy Reform Institute and China National Renewable Energy Centre 2019, p. 8. However, the report does not specify what this economic improvement is about.
194 Aklin and Urpelainen 2018, p. 202.
195 Deese 2017, pp. 89–90.

3.2.2. China's socio-technical energy regime

Culture

Cultural factors influencing China's readiness to embrace the energy transition are difficult to assess and prone to speculation. For instance, Gallagher (2013) traces the acceptance of the Chinese population to RE back to a historically rooted long-term orientation. Accordingly, she claims that the Chinese population cares as much about the long-term future as it cares about the country's long history. Together with the planning tradition of the Communist Party, these cultural values manifest in '[…] a long-term renewable energy plan and […] relatively large and steady investments in renewable energy.'[196]

From the residents' perspective, an online survey of urban residents in 31 Chinese cities has provided a characterisation of their energy consumption awareness and behaviour, which is shaped by 'traditional energy-saving habits, educational background and work environment, energy saving information from social networks, economic concerns, and comparison with neighbours'.[197] Traditional energy-saving habits hint to practices such as turning of heating and cooling when not needed as well as opening windows for ventilation. These habits are distorted by technologies which require to be turned on permanently or ventilation systems which require windows to stay closed.[198] Another theory purports that Chinese homes shape family's identity to a significant extent. As a result of self-expression, homes are spaces to 'display personal success and wealth', with implications for energy consumption behaviours as well.[199]

Generally, the environmental awareness of the Chinese population has increased in recent years, illustrated by the example of Beijing residents, who have reportedly gained a deeper understanding of the city's pollution.[200] In addition, a survey in Chongqing has shown that residents are aware of China's need for an energy transition, but lack knowledge on concrete energy-saving actions at home. Furthermore, they were uninformed about relevant government policies, indicating that such information needs to be disseminated more comprehensively.[201]

Industry

From a macro-economic perspective, the Chinese economy has been leaving the old growth model with its focus on heavy industry behind, while incrementally shifting towards 'domestic consumption, higher value-added manufacturing and services'[202] instead. China's industrial

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196 Gallagher 2013, p. 66. However, Gallagher exclusively refers to cultural science research by Geert Hofstede, whose findings remain controversial. Scholars question the validity of his research because of methodological flaws such as representativeness and assumptions underlying his quantitative data. See MacSweeney 2002, pp. 112–113.

197 Hu et al. 2017, p. 27.

198 Hu et al. 2017, p. 35.

199 Andrews-Speed and Ma 2016, p. 27.

200 China Development Brief 5/29/2018.

201 Andrews-Speed and Ma 2016, p. 28.

202 International Energy Agency 2017b, p. 478.

sector accounts for the largest share of domestic energy consumption, nowadays accounting for roughly 50 percent of China's total final energy consumption.[203] Moving away from low-value production activities towards a stronger emphasis on the commercial and services sector will enable the Chinese industry to save CO_2 emissions. DES will benefit as well, as large power loads to operate factories will be replaced by smaller, more distributed energy loads to supply office buildings and 'smaller industrial facilities'.[204] Indeed, this economic shift, along with increased efforts to improve energy efficiency, has already translated into slower energy demand growth. While energy demand has grown at 8 percent annually between 2000 and 2010, it has slowed down to 3 percent since 2010. Also, along with the expansion of RE in China, the Chinese industry has been able to reduce its use of coal and oil.[205]

As highlighted earlier, Asia is among the continents in which the dominance of monopolies in the energy sector is most prevalent.[206] This applies to the Chinese energy sector as well. Before the latest reforms, the Chinese energy system was characterized by close government control and the dominance of a few incumbent enterprises. Government authorities were responsible for pricing electricity generation, as well as determining maximum yearly operation hours for power plants.[207] The State Grid Corporation of China (in the following abbreviated as 'State Grid') is not only the largest public utility in China but it owns and manages energy assets worldwide, such as in the Philippines, Brazil, Portugal, Australia, Italy and Greece. It was founded as a state-owned enterprise (SOE) in 2002 and is in charge of the investment in as well as construction and operation of power grids.[208] Nowadays, the energy industry is dominated by 20 SOEs, which originated from former ministries. These energy SOEs own and operate the majority of generation assets, obligating generators to sell their generated energy either to State Grid or Southern China Power grid, the two 'single buyer[s] and retailer[s] of electricity within their respective control areas'.[209] Although not explicitly asking for a liberalisation of energy generation, the IEA suggests to 'level the playing field for DES in China and unlock the DES contribution to China's energy transition' through relevant reforms in the fields such as electricity system.[210] This suggests that the dominance of these two grid operators may pose an obstacle for the expansion of distributed energy. The central government seems to acknowledge this obstacle, announcing to liberalise the market for DES on the side of the users as to offer fair access to the grid, while reforming the operation mode of grid enterprises.[211] The exact extent to which the influence of the incumbent grid operators shall be limited remains unclear.

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203 International Energy Agency 2017b, p. 478.
204 International Energy Agency 2017a, p. 12.
205 International Energy Agency 2017b, p. 471 Coal use, however, has decreased 'three straight years since 2013'. The report does not highlight the reason for this limited period of decrease.
206 Moomaw et al. 2012, p. 196.
207 International Energy Agency 2017b, p. 545.
208 State Grid Corporation of China 2019.
209 International Energy Agency 2017b, p. 501.
210 International Energy Agency 2017a, p. 13.
211 National Development and Reform Commission of China 12/26/2016, p. 38.

Markets and user preferences

China plays a leading role in the global market for RE technologies, spearheading the export of solar equipment as well as the development of a major subset of low-carbon technologies. Regarding installed capacities for hydropower, wind energy and solar PV power, China ranks first worldwide. In addition, Chinese companies increasingly invest in international energy projects.[212]

With regard to DES, countries worldwide have recognised the economic potential of distributed energy, including China. As a result, new business models in the field of DES are increasingly offering users a diversified set of energy services rather than just energy alone.[213] Examples of such business models include *prosumer* models and *energy service companies* (ESCO) models. In the *prosumer* model, users become both energy consumers and producers. Modular DES installations allow covering energy demand of private households, communities or industrial parks. *Prosumers* can feed excess energy into the central grid in exchange for remuneration. In the ESCO model, distributed energy developers supply consumers with energy. These ESCOs can cooperate with multiple partners, including utilities, equipment manufacturers and technology providers. [214]

However, research on the user perspective has identified a mismatch between RE technologies and user preferences. Hu et al. (2017) found that there is a gap between policy-making and technological design of RE technologies and the actual energy consumption behaviour of China's urban population. This mismatch can lead to inaccurate technology recommendations, e.g. for heating technologies. For example, whereas experts and media reports strongly advocate technologies for centralised space heating, this may not reflect user preferences but lead to inefficient energy use and higher costs for residents instead.[215]

Policy

Similar to the global socio-technical energy regime, Chinese energy policy has seen an increased public and institutional awareness of the need of an energy transition.[216] The Chinese government has recognised the severity of environmental and health problems arising from the dominance of fossil fuels and has become increasingly active in adapting policy-making to the need for a more sustainable domestic energy system.

China's ratification of the Paris Agreement in 2016 has demonstrated the country's ambitions to contribute to global efforts for climate change mitigation. In its NDCs, the country has committed to 'peak carbon emissions no later than 2030, increase non-fossil fuels to 20 percent

[212] International Energy Agency 2017b, p. 471.
[213] International Energy Agency 2017a, p. 12.
[214] International Energy Agency 2017a, p. 45; International Energy Agency 2017a, p. 48.
[215] Hu et al. 2017, p. 19.
[216] Fischer 2018, p. 8.

of the energy mix, and reduce carbon emissions per unit of gross domestic product (GDP) by 60 to 65 percent from 2005 levels by 2030.'[217] The Chinese NDCs encompass goals such as building a 'low carbon energy system', which purports to curb domestic coal consumption while promoting natural gas, hydro power, nuclear power, solar power, geothermal energy, bio-energy as well as maritime energy. They include the expansion of distributed energy in combination with smart grids too.[218]

Commitments to contribute to reduce energy-related emissions have also manifested in national policies. Main institutions in Chinese energy policy are the National Energy Agency (NEA), which formulates energy-related FYPs and other, quantitative targets as well as regulations for the energy transition. Other relevant ministries include the Ministry of Industry and Information Technology (MIIT), responsible for the 'macro-management of manufacturing capacity on solar photovoltaic (PV) panels and wind turbines', the Ministry of Finance, responsible for budget and subsidies, as well as the National Development and Reform Commission (NDRC) and the Ministry of Commerce (MOFCOM) for overseas projects.[219]

Acknowledging the need to optimise the domestic energy sector, multiple official documents have been released on different administrative levels. On a website called *China Climate Change Info-Net*, the National Centre for Climate Change Strategy and International Cooperation has collected laws and regulations related to climate change mitigation.[220] Apart from the regulations listed there, other policies and guidelines published already during the period of the 12th FYP (2011-2015), for instance, include the *Work Plan for Controlling Greenhouse Gas Emissions*, the *Comprehensive Work Plan for Energy Conservation and Emission Reduction*, the *12th Five-Year Plan for Energy Conservation and Emission Reduction* and the *2014-2015 Action Plan for Energy Conservation*.[221]

The 13th FYP (2016-2020) dedicates an entire section to the energy transition. It announces that China will build 'a modern energy system that is clean, low-carbon, safe, and efficient, and will safeguard the country's energy security.' Whereas the 13th FYP pledges support for projects related to 'main power grids and trans-regional power transmission routes'[222], there are few signs of an official intention to promote local energy generation. Such signs can be found in the government's commitment to promote the expansion of distributed energy systems (DES) as well as support for key technologies relevant for DES.[223] Also, one may recognize subtle hints behind phrases such as '[c]oordinate the development of end-use markets and power

[217] Natural Resources Defense Council 2015, p. 3.
[218] National Development and Reform Commission of China 2015, p. 7.
[219] Shen and Xie 2018, pp. 3–4.
[220] See China Climate Change Info-Net, http://en.ccchina.org.cn/. Rather than a chronological overview of relevant policies, the website merely provides summaries by the NDRC.
[221] National Development and Reform Commission of China 2015, p. 3.
[222] Central Committee of the Communist Party of China 12/7/2016, p. 84-85.
[223] Central Committee of the Communist Party of China 12/7/2016, p. 85; International Energy Agency 2017a, p. 12.

transmission routes' and '[a]ccelerate the development of dispersed wind power and distributed photovoltaic power […]'. These measures implicitly express the intention to involve the local level more deeply in the national energy transition. Yet, the goal for distributed energy has a clear focus on the sources of RE rather than the local organisation of RE generation. Overall, the 13th FYP emphasises larger, trans-regional energy projects such as transmission routes and large power plants over the support for local energy projects.[224] This could suggest that decision-making for the local organisation of the energy transition is directly passed onto energy-related official authorities and lower administrative levels.

More emphasis on distributed energy can be found in documents such as the *National Innovation and Action Plan for the Energy Technology Revolution*, jointly released by the NDRC and the National Energy Agency (NEA). In this document, distributed energy constitutes one of the focus areas for technological development, together with power storage, smart grids and energy savings in industry, buildings and transport. Concrete measures for the promotion of distributed energy include improvements of storage capacities for distributed micro-grids. By 2050, DES shall be scaled up for broad use.[225]

Another document released by the NDRC, the *13th FYP for Energy Development*, stresses the development of distributed energy as well, along with smart energy supply and consumption. It also explicitly emphasises the role of localities and local users, saying that energy generation through DES will be adapted to regional conditions and thus reduce their dependence on fuel imports. Hence, distributed energy is supposed to contribute to regional energy self-sufficiency. Users, i.e. local stakeholders are supposed to both benefit from and take active part in distributed energy generation.[226]

Science

The afore-mentioned *Innovation and Action Plan for the Energy Technology Revolution* indicates where future research should go, with distributed energy being one of the relevant fields.[227] According to the *Innovation and Action Plan*, the Chinese energy sector lacks innovativeness, which is illustrated by four major challenges. Firstly, the Chinese energy sector relies significantly on the import of key technologies, equipment and materials, while indigenous RE technology development has lagged behind. Secondly, industry and research are too detached from each other, inhibiting the transfer of innovation to industrial processes. As a result, Chinese enterprises lack innovativeness. Thirdly, the Chinese innovation system needs to be improved by giving the market a more prominent role for the allocation of resources in science and technology. IP protection needs to be enhanced, along training sessions and management of skilled personnel. Fourthly, the Chinese energy sector lacks a long-term

[224] Central Committee of the Communist Party of China 12/7/2016, p. 86-87.
[225] National Development and Reform Commission of China; National Energy Agency 2016, p. 6; 13; 76.
[226] National Development and Reform Commission of China 12/26/2016, p. 13.
[227] National Development and Reform Commission of China; National Energy Agency 2016, p. 88.

innovation strategy which emphasises the role of science and technology.[228] Although the Chinese government ultimately strives for independent energy innovation, in order to improve its innovation capacities, China will seek international research cooperation.[229]

Technology

Analogous to the global socio-technical energy regime, energy technologies in China have seen improvements in energy efficiency, although this includes fossil-fuel technologies as well. For instance, China has installed a fleet of 'relatively efficient' coal-fired power plants with air pollution controls over the past decade.[230] Although the improved energy efficiency of these power plants can be seen as an advantage, one can also argue that their presumably extensive life-cycle will delay their replacement by more sustainable energy generation units, as reasoned in chapter 3.1.2. Yet, Chinese grids are too inefficient to absorb a large amount of RE, leading to significant losses through curtailment. In 2016, for instance, China had to curtail 50 terawatt hours (TWh) of wind energy due to limited grid capacities.[231]

However, the advantages of distributed energy mentioned in chapter 3.1.2 can help overcome technological challenges. By promoting distributed energy, the Chinese energy regime may benefit from lower energy transmission losses, lower environmental pollution due to cleaner energy sources, reliable energy supply in remote areas, and a level playing field in the energy market through the entrance of decentralised energy providers.[232]

By giving an overview of different trends and factors, this analysis has shown that there are both favourable and unfavourable regime elements in the Chinese energy sector. While official documents indicate that government provides guidance for multiple regime elements such as *industry*, *policy* and *science*, there remain challenges for the expansion of RE which need to be solved. Such challenges include, for instance, lacking knowledge of energy-saving measures among the population, the dominance of incumbent utilities, inaccurate technology recommendations, low innovativeness of Chinese enterprises and deficient IP protection for innovators. **Table 4** summarises the identified elements in the Chinese energy regime.

The next chapter will analyse the role of RECs in China, underpinned by two case studies. The first case study, the *Sunflower Project* in Shaanxi constitutes a grassroots initiative, whereas the second case, *Tongli New Energy Town* in Jiangsu describes a pilot project selected by government authorities. After analysing the development of these two niches in an analogous manner to chapter 3.1.3, their results will be compared and analysed in chapter 3.3.

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[228] National Development and Reform Commission of China; National Energy Agency 2016, p. 4.
[229] National Development and Reform Commission of China; National Energy Agency 2016, pp. 6–7; Fischer 2018, p. 10.
[230] International Energy Agency 2017b, p. 477.
[231] International Energy Agency 2017b, p. 59.
[232] Li et al. 2017, p. 4.

Table 4 Overview of elements in the international energy regime. (Own table)

Culture	Industry	Markets and user preferences	Policy	Science	Technology
• Long-term orientation • Increased awareness • Habits • Identity • Lack of know-how	• Economic shift • Incumbent grid operators • Reliance on fuel imports	• Market leader • New business models • Mismatch with user needs	• Official documents • NDRC and NEA targets	• Official focus areas • Lack of innovative-ness	• Improved energy efficiency • Inefficient grids • Benefits of distributed energy

3.2.3. Niches in the Chinese socio-technical energy system

Parallel to the international counterpart, the Chinese socio-technical energy system has seen an increased number of RECs on the niche level as well. However, as suggested in chapter 2.2.3, the role of Chinese RECs in the MLP is different from RECs in other countries. Differences range from initiation and implementation of such niche projects on the micro-level to their functions within the broader system on a macro-level.

Despite the growing number of Chinese RECs, according to Lou (2013), only a small number of Chinese cities fulfil the conditions to become 100 percent renewable pilot cities, whereas the large majority of Chinese cities are unlikely to become completely renewable.[233]

As mentioned previously, characteristics of RECs vary not only across countries but also within regions. Consequently, Chinese RECs can diverge from each other significantly. The following analysis of two Chinese RECs attempts to capture key similarities and differences in comparison with each other as well as with the international reference from chapter 3.1.3. The Shaanxi *Sunflower Project* (陕西向日葵行动) is an example of a completed renewable energy initiative in rural villages which was initiated bottom-up by a local Chinese non-government organisation, whereas Tongli New Energy Town (同里新能源小镇) is an ongoing model project for showcasing the integration of multiple state of the art RE technologies in one comprehensive energy system. In order to make the international reference, which consists of several case studies, and the two Chinese cases comparable, the next sections will follow the previous approach by focusing on the aspects *initiation*, *government involvement*, *stakeholder participation* and *function of the niche* after a brief introduction.

[233] Lou 2013, p. 34. However, he does not explain why, so one can only assume that other cities may have issues related to geographic and topographic conditions or funding.

3.2.3.1. Shaanxi *Sunflower Project*

In Shaanxi province, which is located in the centre of China, rural regions suffered from environmental pollution, along with increasing costs for food and energy. To curb deforestation, which served at supplying villagers with wood for cooking and heating, the local government incentivised households to keep pigs. However, the pigs produced a critical amount of methane and were thus both polluters of groundwater as well as a valuable source of biogas. Responding to these circumstances, the local civil organisation *Shaanxi Volunteer Mothers Association for Environmental Protection* (陕西省妈妈环保志愿者协会), also called *Mama Huanbao* (MMHB) developed the idea to install small biogas units in each household.[234] The *Sunflower Project* (向日葵行动) began in 1999 and was active in multiple villages in Shaanxi province. In 2006, MMHB was awarded the *Ashden International Award for Sustainable Development* for the accomplishments of the *Sunflower Project*. It was the first Chinese civil organisation to obtain this international award.[235] Upon the award ceremony, Wufang Xiaowei, former director of *Friends of the Earth* (FOE) *Hong Kong* praised the grass-roots organisation for its achievements in empowering rural women and initiating an 'energy revolution' by improving rural pigsties, toilets and kitchens.[236] Yet, since the latest information on relevant activity was published on their website at the end of 2012, it remains unclear if the initiative is still active.[237] Nevertheless, it serves as a successfully completed example of a renewable grassroots initiative on the niche level. It should be noted, however, that the *Sunflower Project* spans across different villages in Shaanxi province and is thus to be seen as a renewable energy region rather than a city.

Initiation

The *Sunflower Project* was initiated by the local civil organisation MMHB in 1999. Founded by Wang Mingying in 1997 under the management of Shaanxi Women's Federation, the MMHB's initial mission was to contribute to afforesting the hillsides around villages in the province, raising money for tree planting activities.[238] As a result of deforestation and over-ploughing, the rural region had been suffering from increasing 'desertification, frequent dust storms and weak springtime river flows', and it was affected by polluted air and water.[239] The contamination of groundwater by animal waste eventually impaired hygiene and threatened the health of the rural population. To address these problems, the members of MMBH decided to seek an alternative energy source to solve these pollution problems, which were adding to the financial burden of high energy costs.[240] Hence, the impulse to replace the local fossil fuel-based energy system with RE came bottom-up from civil society. Jointly with the non-

[234] Radzi 2012, p. 133.
[235] Radzi 2012, pp. 132–133; Shaanxi Volunteer Mothers Association for Environmental Protection 2012.
[236] Shaanxi Volunteer Mothers Association for Environmental Protection 2012.
[237] See Yu 2011.
[238] Ashden 2008.
[239] Radzi 2012, p. 133.
[240] Radzi 2012, p. 133; Yu 2011.

government organisation *Friends of the Earth Hong Kong*, MMHB initiated the *Sunflower Project* as a regional biogas model project.[241] MMHB's first step for drafting a project concept was to reach out for the help of 'local agencies and experts in the fields of farming, veterinary science, energy and technology.'[242]

The first individual biogas installations in rural households began in seven villages in Baota, Yan'an in 1999.[243] The methane-based biogas from the pigsties could be used in three ways, i.e. to fuel electricity, cooking and heating.[244] **Figure 9** visualises the cycle in which methane produced by the pigs is transformed into energy for the household. Together with human excrement from the toilet, the pig waste is accumulated in an underground methane reservoir, where it is turned into biogas through bacterial decomposition. The biogas is then 'piped into the house and connected to a two-ring stove for cooking, a lamp for lighting and occasionally a water-heater for showers.'[245] The semi-solid residue resulting from the decomposition as a by-product can be reused as agricultural fertiliser. Under appropriate maintenance, these biogas plants have a life-cycle of at least 15 years. The biogas digester, on which the biogas system is based was developed by a professor from Northwest Agriculture and Forest University in Xianyang city.[246] Components of this system were manufactured in different parts of China and could be delivered to Shaanxi province.[247]

[241] All-China Women's Federation 2007.
[242] Radzi 2012, p. 133.
[243] Radzi 2012, pp. 134–135.
[244] Radzi 2012, p. 133.
[245] Ashden 2008.
[246] Wheldon and Rawlings 2006, p. 2.
[247] Ashden 2008.

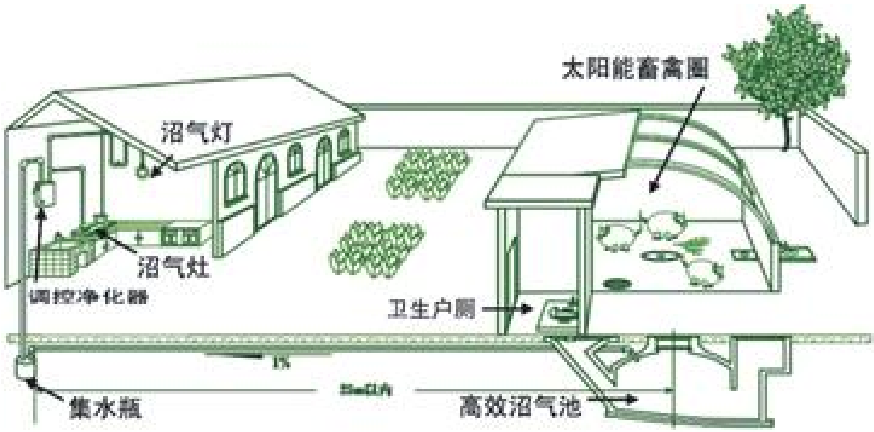

Figure 9 Overview of biogas usage for electricity, cooking and heating in private households.(Shaanxi Volunteer Mothers Association for Environmental Protection (2012))

Apart from installing individual biogas utilities in private households, MMHB also promoted public activities related to environmental protection, conducted capacity building workshops for women engaging in environmental protection, launched projects for the conservation of drinking water and for disaster relief construction, and initiated exchange with international environmental organisations. Their projects were not only able to supply rural households with clean energy, but they also improved local sanitation, pig pens, and kitchen stoves. In addition, improvements in local agricultural processes increased household incomes.[248]

Stakeholder participation

The *Sunflower Project* welcomed the participation from stakeholders in idea finding and decision-making throughout the entire planning and implementation process, encouraging them to contribute ideas from 'initial assessment of a new plant to commissioning'.[249] Already during the initiation of the *Sunflower Project*, interested local stakeholders were invited to meetings and workshops in which potential households were selected and educated thereafter. Under the guidance of experts in technology and agriculture, participants learned about 'environment and health, the food chain, renewable energy, waste collection, pigsty and toilet retrofit, pipe laying to transmit methane, equipment operation, maintenance and repair as well as recovering residue for fertilizers and organic farming.'[250]

A substantial part of MMHB's work built on stakeholder empowerment. Apart from the installation of household biogas units, workshops and training sessions became another major activity of MMHB. Often, these workshops were conducted in cooperation with other Chinese or international NGOs and involve experts and professors.[251] From 2008, MMHB cooperated

[248] Yu 2011.
[249] Wheldon and Rawlings 2006, p. 3.
[250] Radzi 2012, p. 133.
[251] Yu 2011.

with *Give2Asia* foundation, a US-based NGO active in local communities in Asia, to offer workshops in 35 villages. 101 individuals were educated to take leading roles for technical services related to the households' biogas units, and maintenance teams were established in 31 villages. All in all, 236 people in 38 villages were educated to maintain their own biogas systems, and 1,380 individual biogas households received additional training.[252] With the help of these workshops, local villages were provided with guidance and training which enabled them to manage their own biogas systems. Throughout MMHB's activities, empowerment of women was particularly emphasised.[253] The biogas scheme helped them to save time so that they could engage in, for example, social activities.[254] Hence, the biogas units also improved their social lives.

Local stakeholders in general perceived the private biogas systems as a convenient improvement, as the project reduced their daily workload and provided them with clean energy available on-demand.[255] As Ashden (2008) observed, on-demand availability of energy 'saves time collecting wood and in preparing fires for cooking. Users enjoy being able to prepare a meal much more quickly using biogas and not having to endure a smoky kitchen.'[256] By 2006, 1,294 biogas plants had been installed, benefitting roughly 5,200 people in total. According to latest accounts, MMHB helped to install biogas utilities in 2,542 households in 58 villages in the end.[257] As a result, both the air quality in households and groundwater quality could be improved by reducing the concentration of carbon monoxide, sulphur dioxide and dust, and preventing pig waste from seeping into the groundwater.[258] Thus, the biogas scheme was able to mitigate health risks for the rural population.

With regard to financing the installation of biogas units, households received financial support from both MMHB and the local government. Depending on its size and features, the price of an individual biogas plant ranged from 3,500 to 4,500 RMB. While the household usually paid one third 'in labour and cash'[259], another third was financed by local and central subsidies and the final third was paid by MMHB. The funding from MMHB was in turn financed by NGOs and international government bodies such as the German Embassy, as well as from donations and public fund-raising activities.[260] However, in 2006 the demand for private biogas installations exceeded the possible budget, so that village authorities selected the recipients of financial support. To this end, the local party secretary and elected village headman decided

[252] Ashden 2008; Yu 2011.
[253] Radzi 2012, pp. 134–135.
[254] Ashden 2008.
[255] Radzi 2012, pp. 135–136.
[256] Ashden 2008.
[257] Ashden 2008; Shaanxi Volunteer Mothers Association for Environmental Protection 2012 The sum of benefitted individuals is based on the assumption that the average households consists of about four people.
[258] Ashden 2008.
[259] Ashden 2008.
[260] Wheldon and Rawlings 2006, p. 2.

based on the number of beneficiaries, the number of pigs (at least four) and the size of the pigsty.[261]

At the same time, households were able to save expenditures for fuel and fertiliser. Ashden (2008) calculated possible savings as follows:

> A biogas plant reduces household expenditure on fuel and fertiliser. One 8 to 10m3 biogas plant can supply a family of three to five people with enough gas for 90% of their daily fuel needs for 10 to 11 months of the year. This saves about US$75 per year (600 RMB) on fuel (coal or wood), US$40 per year (300 RMB) on fertiliser and US$20 per year (150 RMB) on electricity (through use of biogas lamps).[262]

Thanks to the resulting income increase, households could break even in one to two years.[263]

The afore-mentioned benefits contributed significantly to the stakeholders' acceptance of the *Sunflower Project*, which was especially reflected in the prestige connected to the households' participation. Households selected for biogas subsidies attached donor plaques on their front doors, and rooftop solar PV panels evolved into status symbols.[264]

Government involvement

Throughout the *Sunflower Project*'s activities, MMHB cooperated with different partners. Whereas many cooperation partners were NGOs, such as FOE and *Give2Asia*, other activities involved the support of government bodies, both on the provincial and the international level. For instance, during the organisation of events for public awareness rising, MMHB did not only receive support from Shaanxi Women's Federation, but also from the provincial Development and Reform Commission (DRC) and the Department of Environmental Protection of the local government.[265]

Table 5 provides an overview of different government and non-government cooperation partners of MMHB's *Sunflower Project*. Donors include NGOs, such as Macao-based Badi Foundation for Village Capacity Building, Hong Kong-based FOE, Friends of Nature, Give2Asia, Global Biogas Capacity Building Project, Global Fund for Women, and Global Women Cooperation, as well as the World Bank. From the official side, the German Embassy and Chinese local government agencies such as the Shaanxi Province Hydrology Office also contributed financially.

[261] Ashden 2008; Wheldon and Rawlings 2006, p. 2.
[262] Ashden 2008.
[263] Wheldon and Rawlings 2006, p. 3.
[264] Radzi 2012, p. 135
[265] Yu 2011.

Table 5 Overview of partners and donors of Shaanxi *Sunflower Project*. (Based on Radzi 2012, p. 135 and Shaanxi Mothers Environmental Protection Volunteers' Association 2011)

NGO partners	Government partners
• Badi Foundation for Village Capacity Building • FOE Hongkong • Friends of Nature • Give2Asia • Global Biogas Capacity Building Project • Global Fund for Women • Global Woman Cooperation • Shaanxi Women's Federation • World Bank	• Shaanxi DRC • Department of Environmental Protection • German Embassy • Local government agencies (e.g. Shaanxi Province Hydrology Office)

Function of the niche

According to MMHB's estimates, each biogas household was able to save roughly 4.5 tonnes of wood and 6 tonnes of CO_2 emissions per year, including both direct emissions from burning coal and wood as well indirect methane emissions from pig manure. Consequently, the 1,294 biogas plants installed in 2006 reduced CO_2 emissions by approximately 8,000 tonnes per year.[266] Hence, from a macro-level perspective, the *Sunflower Project* contributed to the overall emission reduction goal as stipulated by the central government, although the exact extent of the project's contribution remains difficult to quantify.

On the niche level, MMHB was well-connected locally and received funds for their activities from various other civil organisations. For instance, an elementary school donated its revenues from a recycling initiative to finance MMHB's tree planting activities.[267] This shows that MMHB was embedded in a network that spans several stakeholder groups on the niche level, which corresponds to the characteristic interconnection of stakeholders both within and across actor networks on the niche level. Also analogous to the role of the niche in the MLP, the Shaanxi biogas scheme was mainly carried out by MMHB and the network it built with rural residents, other NGOs and government bodies, all of which were active locally.

In addition, almost all of the four niche development phases described in chapter 2.1.3 can be found throughout the initiation and implementation of the *Sunflower Project*. Analogous to the first phase, in which a technological innovation serves at solving a specific local problem, MMHB decided to turn animal waste into a source of energy, combatting the pollution of rural environments and mitigating the resulting environmental and economic costs for the villagers. Expert workshops and trainings organised by MMHB resemble the expert groups who advance

[266] Ashden 2008 However, these numbers lack actual quantification.
[267] Yu 2011.

and improve the innovation in the second phase. MMHB was also actively involved in expanding such expert groups, educating and empowering rural residents to maintain the biogas units.

In the third phase, technological and economic improvements of the technological novelty are supposed to decrease average costs and increase the innovation's competitiveness. However, the Shaanxi biogas scheme shows no sign of such economies of scale. Quite the contrary, subsidies from MMHB and the local government make it unnecessary to improve the competitiveness of these biogas units, indicating that the Shaanxi *Sunflower Project* may have been able to leapfrog this phase with the help of financial support. Nevertheless, the biogas technology underlying the *Sunflower Project* found imitators in rural areas of Jiangxi, Shandong and Sichuan provinces as well.[268] Hence, the third phase is partly completed.

Finally, the fourth phase, in which the new technology replaces the dominant one has been realised to a large part as well. Apart from certain dishes the villagers still prefer to prepare in their coal-fired ovens, biogas has replaced coal and wood as a source of electricity in all applications, i.e. cooking, heating and lighting.[269] With the exception of a few diverging practices, the Shaanxi *Sunflower Project* altogether underwent all relevant phases of niche development (see **Table 6**). The fact that it leapfrogged the third phase gives room to the hypothesis that active financial support or even government support, where applicable, makes it unnecessary for the innovation to become competitive on its own. This has further implications for the overall role of RECs in China in the context of *experimentation under hierarchy* and strategic niche management, which will be analysed more in-depth in chapter 3.3.

Table 6 Niche development phases in Shaanxi *Sunflower Project*. (Own table.)

Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
X	X	(X)	X

The positive influences of MMHB's *Sunflower Project* reached beyond the province of Shaanxi. Other villages expressed their respect for the readiness of the rural population in Shaanxi to adopt the new technology, MMHB's entrepreneurial and fundraising capacities and the association's persistence in light of bureaucratic challenges.[270] The technology underlying the Shaanxi biogas scheme was adopted in the rural regions of Jiangxi, Shandong and Sichuan provinces as well.[271] Although merely duplicating one niche innovation into another niche does not yet correspond to the niche-regime logic of the MLP, the possibility that influences from the niche reach up into the regime level in which policy-making takes place cannot be excluded.

[268] Wheldon and Rawlings 2006, p. 2.
[269] Ashden 2008.
[270] Radzi 2012, pp. 136–137.
[271] Wheldon and Rawlings 2006, p. 2.

As shown previously, the local government of Shaanxi is involved in the *Sunflower Project* to a crucial extent. Since it contributes to financing the installation of biogas units in private households and selects recipients of installation subsidies, it has an immediate stake in the *Sunflower Project*. At the same time, the local government works as an extended arm for the implementation of central climate policies. As the central government and related government bodies, such as the NEA have enshrined emission reduction and clean energy targets in several official documents, the local government of Shaanxi plays a bridging role for the realisation of these targets on the local level.

Given the importance of RECs in the context of policy experimentation and in view of the success of the Shaanxi biogas scheme, it is not unlikely that the innovation from the Shaanxi niche permeates higher administration levels and feeds into central policy-making. Hereby, the biogas innovation has the chance to dominate the Chinese socio-technical energy regime. However, since not all Chinese cities will necessarily become entirely renewable, and biogas schemes are only suited for RECs with a similarly high reliance on agriculture, an absolute dominance of biogas schemes in the Chinese socio-technical energy system is rather improbable, but still possible in the sub-system of the rural energy transition.

3.2.3.2. Tongli New Energy Town

Tongli town, located in Wujiang district of Suzhou, Jiangsu province, is primarily known for its historic city centre and its numerous old canals. With an area of 33 hectares, the population of Tongli counts 58,000 people. Apart from its scenic reputation, however, Tongli is moving to the forefront of RE as well. Embedded into the broader *Wujiang Economic and Technological Development Zone* (WETDZ), Tongli is one of several towns in WETDZ to explore emerging industries, such as *new energy*, and is in search of international investors, as introduced by the Wujiang District Government on its website.[272] Hence, the REC of Tongli is part of a broader strategy for regional development. At the second *International Forum on Energy Transitions* (IFET) in Tongli in October 2016, Jiangsu Electric Power Co. Ltd. (in the following abbreviated as 'Jiangsu Electric'), the provincial subsidiary of State Grid, and the municipal government of Suzhou city announced they would turn Tongli into a model town for the international energy transition, and coined the 'Green Tongli Model' for the promotion of the energy transition.[273] The official *Tongli New Energy Town Construction and Development Plan* followed in November 2016, developed by the Tongji University School of Urban Planning and Design in Shanghai.[274] Planned to be completed by 2022, TNET will be built in the historic city centre, where the major share of Tongli's energy use is concentrated.[275] On an area of roughly 3 km^2,

[272] See Suzhou Wujiang District Government 2018.
[273] Long et al. 2018, p. 93.
[274] Suzhou Wujiang District Government 11/4/2016. However, this official document is not publicly available. Instead, one finds scattered accounts online which briefly refer to the document and take up specific elements.
[275] Deutsche Energie-Agentur 2018aa; 2018b.; Long et al. 2018, p. 93.

TNET is designed to integrate electricity, heating and cooling and transport into a holistic RE system.[276]

However, there is little academic research on TNET. Apart from an extensive video report and two academic articles, the relevant body of literature mainly consists of official press releases by the local government, official government agencies and the German Energy Agency (dena), as well as diverse reports on news websites.

Initiation

As opposed to the Shaanxi *Sunflower Project*, scattered information on Tongli indicates that the town was selected top-down as an RE experimentation zone. Yet, the exact factors that led to the establishment of TNET remain vague. Long et al. (2018) argue that Tongli took part in a joint initiative by the Ministry of Housing and Urban-Rural Development (MoHURD), Ministry of Finance (MoF) and the NDRC. In their *Notification of the Launch of Cultivation Work for Unique* Towns (关于开展特色小镇培育工作的通知), the three ministries announced it would foster 1000 'unique and vigour'[277] towns for leisure, trade and commerce, modern manufacturing, educational technology, and traditional culture. Since Tongli possessed an already pronounced RE industry, this may have qualified the town for this government initiative.[278] Notwithstanding, renewable energies receive no particular attention in the official notification, and hence, the authors' argumentation lacks clear evidence.

Nonetheless, Suzhou was among the three batches of 'low-carbon provincial area and city pilots' (低碳省区和城市试点) selected by the NDRC between 2010 and 2017.[279] It is thus possible that Tongli was selected by the Suzhou government in line with the NDRC's call for low-carbon pilot projects. Before being approved, the *Tongli New Energy Town Construction and Development Plan* had to undergo a technical review by the Water Conservancy and Hydropower Planning Unit of the NEA Department for New Energy, the National Renewable Energy Centre and other relevant units.[280] This shows that from the beginning, TNET had close contact to central government bodies.

The establishment of TNET is divided into two phases, i.e. in a construction phase from 2016-2020, and a subsequent improvement phase. The result will be an REC with "low energy consumption, an innovative model, broad application, high efficiency and unique features".[281] By 2020, TNET is supposed to be nearly 100 percent renewable.[282] With an installed capacity of 121.6 kilowatts (kW), solar PV power is going to account for the major share in Tongli's

[276] Deutsche Energie-Agentur 2018b.
[277] Long et al. 2018, p. 93.
[278] Long et al. 2018, p. 93.
[279] Long et al. 2018, p. 93.
[280] Wujiang Real Estate Web (吴江房产网) 11/2/2016.
[281] China Power News Network 11/23/2016.
[282] Suzhou Wujiang District Government 11/4/2016.

future energy mix, followed by installed capacities of 10.02 kW for wind energy, 1.9 kW for water heat pumps and 0.44 t for biomass energy. On a surface of 2.4 km², TNET will realise the following five key projects: Firstly, it will establish a 'triple supply system' based on ultra-high voltage transmission, megawatt photovoltaic power station and natural gas.[283] Secondly, it will improve capacities for local energy self-sufficiency through a water-fuelled heat pump system in the ancient town district, small solar photovoltaic power stations, and micro-grids as to enable on-site consumption of locally generated energy. Thirdly, it aims to transform the electricity grid by optimizing the distribution network, establishing a smart 'energy internet', and installing energy storage facilities. Fourthly, TNET will promote energy saving by the construction of energy efficient buildings, the application of new technology, supporting green transportation, and reducing energy consumption. Fifthly, TNET's generated energy is supposed to extend to a range of 167km², thus reaching into the wider WETDZ.[284] In addition, it will contribute to the promotion of WETDZ with the help of new energy companies and institutions, technology incubators, and exchange platforms for innovation and training, as to upgrade and demonstrate the national energy transition on the international stage.[285] At present, Tongli is already surrounded by parking lots equipped with charging stations for electric vehicles.[286]

Stakeholder participation

Active stakeholder participation from residents in the design and development plays an important role for TNET. At information events, on digital platforms and applications, in public lectures and in neighbourhood gatherings, residents may express their needs and recommendations.[287] In addition, TNET does not only emphasise the mere application of RE, but also aims to integrate culture and tradition with environmental protection. To preserve the traditional stove as a symbol of Tongli's indigenous culture and history while making it more sustainable, firewood is being replaced by 'green coal', i.e. biomass briquettes, which significantly reduce air pollution. Thereby, customs and habits of local stakeholders are respected.[288] Apart from residents in the ancient town, visitors shall benefit from the convenience and innovativeness of new energy services in TNET as well.[289]

Although there is little information on the concrete design of stakeholder participation, interestingly, Suzhou city utilises internet forums to engage with stakeholders. On a website

[283] As visible from the targeted energy mix, this multi-energy system will still incorporate fossil fuels, which explains why the project design only allows for a nearly 100 percent renewable energy mix.
[284] According to Wujiang fangchan wang, the scope of TNET's energy supply is 176km². TNET's energy supply scope extends to Tongli Township and Wujiang Economic and Technological Development Zone with an area of about 176 square kilometers. Wujiang Real Estate Web (吴江房产网) 11/2/2016.
285 Long et al. 2018, p. 93; Wujiang Real Estate Web (吴江房产网) 11/2/2016.
[286] Long et al. 2018, p. 93.
[287] Deutsche Energie-Agentur 2018a.
[288] Long et al. 2018, p. 93.
[289] Wujiang Real Estate Web (吴江房产网) 11/2/2016.

called 'Suzhou Convenience Service Centre' (苏州市便民服务中心), the operator offers a Q&A feature for local netizens. On 15 November 2016, an online user, presumably a resident of Zhongliang Benyuan community in Wujiang district, asked if there were preferential government policies for the installation of solar PV panels on private rooftops. A staff member replied with a description of current PV subsidies, referring to the 'Notice of the NDRC on Promoting the Sound Development of the Photovoltaic Industry by the National Development and Reform Commission'.[290] The subject of the inquiry – 'Zhongliang Benyuan community is willing to support the construction of TNET' (中粮本源小区愿支持同里新能源小镇建设) – hints to a high acceptance among residents towards the REC project. Apart from this online service, which is commissioned by the Suzhou Municipal Government, TNET established a Centre for Integrated Energy Services, located in the North of the ancient town. Although the centre is mainly responsible for implementing innovative energy technologies, such as electric roads, charging stations, passive houses, and direct current power distribution systems, one may assume that it serves as a contact point for stakeholders and visitors as well.[291]

Unlike the case of Shaanxi *Sunflower Project*, there is no sign that TNET is well-connected to other niche actors. Rather, its network focuses on other official institutions and agencies. Local stakeholders get the chance to meet at information events and other gatherings to voice their ideas, but there have been no reports on trainings and workshops which enable them to actively participate in the local energy transition. In addition, dena (2018a) has been the only source of information on stakeholder participation at the afore-mentioned kind of events, yet, no accounts on the Chinese side have verified such activities so far.[292] Hence, the overall extent to which stakeholders may actively participate remains unclear, although the European cases have proved that niche actors can be a critical success factor for the development of niches.

Government involvement

As shown above, Chinese government bodies have been intensively involved with TNET from the beginning. Selected as a low-carbon pilot city by the Suzhou Municipal Government on order of the NDRC, Jiangsu Electric announced it would actively collaborate with the municipal government in the three-year construction plan of TNET. Thereby, Jiangsu Electric aims at integrating their ideas into the overall government plan, hoping for active government support in policies related to the energy transition. More precisely, Jiangsu Electric hopes for government support in the four fields of action in TNET, i.e. energy storage, grid infrastructure upgrading, smart grid demonstration as well as energy transition demonstration.[293] After the selection of Tongli, the construction of TNET had to be approved by a committee composed of relevant departments and units from the NEA. The NEA has also pledged support for the

[290] Suzhou Convenience Service Centre 2016.
[291] Suzhou Wujiang District Government.
[292] Deutsche Energie-Agentur 2018a.
[293] China Electricity Council 7/22/2016.

establishment of TNET. To what extent these official bodies assessed TNET in the context of China's broader energy transition and related policies, however, remains unclear. After signing the *Agreement for the Construction of a Strong Smart Grid and the Promotion of the Development of the Energy Transition* with the Wujiang District Government, Suzhou Power Supply Company (abbreviated as 'Suzhou Power'), a Jiangsu Electric subsidiary, is also involved in TNET. Responsible for the construction of a smart grid in Tongli, Suzhou Power plays an active role in exploring the afore-mentioned 'Green Tongli Model'.[294]

As **Table 7** shows, the majority of partners involved in the establishment of TNET is composed of government bodies and agencies. The only NGO is the German energy agency 'dena', which assisted the Suzhou Municipal Government in assessing and selecting appropriate technologies and concepts from multiple cities worldwide to be integrated into the concept of TNET, together with the E.ON Energy Research Centre at RWTH Aachen.[295] However, as an executing organ for the German energy transition, dena is closely connected to the German Federal Government.[296] As opposed to the Shaanxi *Sunflower Project*, the civil society is not significantly involved in the establishment of this REC. Instead, government institutions are leading the development of TNET, which has significant implications for the *function of the niche*.

Table 7 Overview of partners of TNET. Based on (China Electricity Council 7/22/2016), (Deutsche Energie-Agentur 2018a), (China Power News Network 11/23/2016)

NGO partners	Government partners
• dena	• Jiangsu Electric
• E.On Research Centre (RWTH Aachen)	• NEA
	• Suzhou Power
	• Suzhou Municipal Government
	• Wujiang District Government

Function of the niche

As the first pilot project for Suzhou, Tongli is designed to serve as a model for the future energy transition and development of the region, implying that other towns are supposed to follow.[297] In addition, the creation of the 'Green Tongli Model' indicates that TNET is designed to be replicated in other cities as well, while Tongli's aspiration to evolve into a permanent conference site for IFET implies that this model shall be imitated not only in China, but also worldwide. This assumption is supported by a step-by-step instruction based on learnings from TNET, which aims at facilitating the initiation of RECs for other cities as well.[298] Firstly, Tongli

[294] China Power News Network 11/23/2016.
[295] Deutsche Energie-Agentur 2018a.
[296] See Deutsche Energie-Agentur.
[297] China Energy Storage 10/27/2017.
[298] Long et al. 2018, p. 93.

compiled a GHG inventory which displays the sources and composition of local GHG emissions. Secondly, Tongli prioritised RE such as wind, solar PV and geothermal in the local energy mix, while retaining natural gas in order to safeguard energy security. Thirdly, TNET took measures to make fossil fuel-based energy sources cleaner and more efficient, such as replacing conventional coal with biomass briquettes for traditional stoves. Fourthly, TNET limited the expansion of energy intensive industries as demanded by the national energy supply reform. However, TNET largely serves as a demonstration of technological innovations related to energy. Analogous to Späth and Rohracher's (2012) observations in Austrian Energy Regions, TNET may rather be seen as a feasibility project designed for technology transfer onto other niches than an incubator of radical innovation for broader transition.[299]

Apart from these differences, the evolution of TNET also diverges from the niche development described in chapter 2.1.3. First, TNET was not primarily created to solve local problems. Instead, Tongli was presumably selected by the Suzhou Municipal Government because WETDZ already provided appropriate industrial infrastructure to build upon. Hence, the first phase of niche development was omitted. The second phase is partly applicable, since relevant government institutions and local subsidiaries of state-owned State Grid assumed the role of expert groups to further improve the innovation. Nevertheless, the composition of this expert group does not entirely correspond with the original idea. The most crucial difference is that the actors in this case are not members of the local community, but rather representatives of the socio-technical regime, since they are either affiliated with government institutions (*policy*) or incumbent utilities (*industry*). This may imply that the improvements of the innovation are not necessarily tailored to local needs and expert groups composed of niche actors may have adapted it differently. Active participation from regime members may in turn signify that the adaptations best fit official narratives and requirements of the innovation. The third phase, in which the cost effectiveness of the innovation is improved by competition is not applicable either. The ongoing infrastructure construction is likely to require significant investment capital, which indicates that TNET would not have survived under normal market conditions. As TNET is commissioned and funded by government institutions, there has been no need to improve the price ratio of the innovation. Yet, government subsidies for the installation of distributed energy systems, as suggested by the conversation between an online user and the Suzhou Convenience Service Centre, may increase the adoption rate for local households. This finding underpins the observation made in chapter 3.2.3.1, indicating that financial support may help to leapfrog this phase. The fourth phase, in which the dominant regime configuration is completely replaced, is almost completed in TNET. With the exception of natural gas, the targeted energy mix of Tongli will be completely renewable. Altogether, TNET did not undergo all development phases of niche innovations, as can be seen in **Table 8**.

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[299] Späth and Rohracher 2012, p. 475.

Table 8 Niche development phases in TNET. (Own table)

Phase 1	Phase 2	Phase 3	Phase 4
	(X)		X

The sum of these deviations from the classical MLP understanding strongly support the hypothesis that TNET has not evolved as a result of spontaneous niche dynamics but through SNM. As visible in **Table 8**, TNET shows similar gaps in the niche development as the cases of Helsinki and Murau, which have been identified as examples for SNM as well. In addition, the pervasive involvement of government representatives, along with the location of TNET in a broader experimentation zone clearly indicate that TNET was established as a pilot experiment.

3.3. Results

Despite wide variations between RECs worldwide, the MLP offers a comprehensive framework for the analysis of both general and specific drivers behind the energy transitions of the respective cities and regions. The framework helps to assess the role of niche innovation in light of broader trends on the landscape level, which are out of reach for purposeful interventions, as well as elements in the energy regime, which represent coordinated interactions between actors and institutions. The comparative analysis across the three levels landscape, regime and niche finally allows comprehending why and how European countries and China engage in the promotion of RECs. Results of the analysis will be presented below.

Why do countries generally promote RECs?

General motivations to foster 100 percent renewable niches can be found on the landscape level. Macro-level developments such as climate change, which is also a cause for resource scarcity, along with progressive urbanisation and digitalisation are increasing energy demand and pressuring nations to develop appropriate measures for climate change mitigation.[300] The US' withdrawal from the Paris Agreement can be seen as another setback for international climate policy, although the impacts of the withdrawal are being debated.

Elements on the regime level explain the relevance of RECs for the energy transition. Facilitated by favourable regime elements, e.g. the increasing decentralisation of energy generation and consumption, transforming cities and regions to 100 percent renewable constitutes a reasonable starting point for achieving an extensive energy transition.[301] Other elements highlight further benefits of such local approaches. For instance, improvements on DES and decreasing costs of RE technologies make local generation and consumption of energy more favourable than centralised energy supply via large grids (*industry*). The expansion of RE in general is supported by increasing public awareness (*culture*), the Paris agreement including

[300] Köhler et al. 2017, p. 21; International Energy Agency 2019, p. 5.
[301] Droege 2006, p. 25.

SDGs and NDCs (*policy*), as well as efficiency improvements and the compatibility of RE with other technologies (*technology*).

However, many regime elements are challenging the expansion of RE globally. For instance, stakeholders may oppose the installation of RE for different reasons (*culture*). The energy market is dominated by energy monopolies and other incumbent actors in many countries. In addition, levelized costs of energy have remained higher than for conventional energy (*industry*). Furthermore, consumers hesitate to invest in RE due to high initial investment and switching costs, paired with other financial insecurities (*markets and user preferences*). Hard institutions, i.e. unfavourable policy frameworks, as well as soft institutions, i.e. conflicts between key stakeholders negatively affect the adoption and acceptance of RE.[302] Lack of data and skills shortage hamper research on RE technologies (*science*), while existing RE technologies often lack capacities. Long life-cycles of old devices and installations, as well as insufficient grid capacities lead to inefficiencies (*technology*). These impeding elements will need to be adjusted in many countries to accelerate the energy transition.

Why does China promote RECs?

Since the Chinese landscape is affected by international developments as well, the Chinese energy system has been struggling with the same landscape drivers as the international energy system, which makes it imperative to transition to cleaner energy sources. Environmental pollution, which affects public health and results in high economic costs, along with continued urbanisation, which will further increase domestic energy demand are key drivers in the Chinese context.

In addition, China has been facing particular pressure for being the largest emitter of GHG worldwide.[303] The central government has recognised both the need to transition towards cleaner energy and the potential of distributed energy. Consequently, official documents, such as official plans and strategies by the NDRC and the NEA aim at promoting the expansion of DES, overarched by the 13th FYP which formulates general goals (*policy*). The expansion of DES in China will ultimately benefit from the shift in the national economic growth model. Shifting away from production-driven heavy industry to a consumption-driven economic model, the demand for large power loads from factories will be replaced by dispersed demand for smaller power loads (*industry*).[304] In addition, the expansion of RE can build on China's leading role in the global market for RE technologies, as well as from promising new business models based on distributed energy (*market*).[305]

[302] Köhler et al. 2018, p. 16-17.
[303] Aklin and Urpelainen 2018, p. 202.
[304] International Energy Agency 2017a, p. 12.
[305] International Energy Agency 2017b, p. 471.

Nevertheless, similar to the international energy regime, China needs to improve certain regime elements. The dominance of state-owned energy utilities such as State Grid and relevant subsidiaries potentially hinders the establishment of decentralised energy infrastructure and conflicts may arise from the obligation for generators to sell energy to their grids (*industry*). In addition, the Chinese energy infrastructure suffers from inefficient grid capacities, although energy efficiency of RE technologies has increased (*technology*).[306]

The example of Köhler et al.'s (2017) application of the MLP, on which the analysis was based, seems to suggest that the framework merely tried to grasp those elements that could be identified easily, while omitting those that did not apply. A broader literature review can circumvent this shortcoming and extend the analysis of the Chinese energy regime with a comprehensive report on relevant regime elements. However, due to the limited scope of this thesis, the applied regime analysis relied mainly on reports by the International Energy Agency (2017a; 2017b). Hence, to verify the extent to which all six elements apply to the Chinese energy regime, future research may refer to a more diversified body of literature.

How do the countries promote RECs?

The comparative analysis of seven European and two Chinese RECs finally delivered answers to how Europe and China promote local energy transitions by highlighting how different RECs emerged and developed. The multi-case report drew from different systematic case studies, all of which are coincidentally located within Europe. However, the RECs were not selected based on their location, but rather with regard to the availability of structured records and a representative diversity throughout their implementation. Concurrently, the cases differ in scope, ranging from sparsely populated villages like Feldheim to large cities like Graz and Freiburg. Accordingly, transitioning towards 100 percent RE is more facile in smaller villages than in larger cities, which may explain why Graz and Freiburg have not yet completely become entirely renewable.

It should also be noted that the results are based exclusively on a collection and interpretation of these case studies, without having made own observations. Furthermore, since these case studies were compiled during 2010 and 2014, this sample does not represent RECs which emerged in recent years. Yet, the fact that the majority of selected cases have been completed allows for consideration of their results and lessons learnt. Finally, although the landscape and regime analyses do not correspond with the time frame of the respective cases, the analyses still provide a valid overview of the energy sector. Since developments on the landscape level are changing slowly, trends such as climate change and urbanisation have not lost their relevance but have rather become ever more important in recent years. Accordingly, regime elements are not expected to have changed significantly, since aspects such as the awareness for environmental degradation (*culture*) or the dominance of incumbent energy utilities (*industry*)

[306] International Energy Agency 2017b, p. 477.

have presumably existed before. This is illustrated by the example of Freiburg, where the plan to construct a nuclear plant had led to significant protests among the citizens in 1970.

In order to assess whether RECs materialised as a result of spontaneous niche development or SNM, four proxy criteria were developed. The criterion *Initiation* aimed at comprehending drivers which had immediately led to the establishment of the respective REC, investigating if the niche had developed an innovative solution for a specific local problem or if organisations had intentionally selected the REC. In some cases, factors leading to the *initiation* of the RECs traced back to a need for solutions to problems that occurred locally. In the case of Graz and Shaanxi, such problems were related to environmental pollution, with the former suffering from poor air quality and the latter from deforestation and polluted groundwater. Facing increasing fuel debts, Güssing saw itself pressured to transition to locally available energy sources instead of importing them. In Freiburg, the planned installation of a nuclear energy plant gave rise to local protests, pressing the municipality to react. Feldheim was forced to construct an independent energy grid as a result of unsuccessful bargaining with the regional incumbent facility.

As opposed to the previous cases, strategic decisions have induced the establishment of the RECs in Helsinki, Jühnde, Murau and Tongli. Whereas Jühnde was designed as a research project by a research institute, the regional energy agency of Murau developed the vision of an Energy Region in cooperation with the help of a facilitator and an activist team. Helsinki and Tongli were both selected by respective government bodies for the purpose of experimentation, which can be seen as a first indicator for SNM.

Although evidence for strategic selection of RECs already corresponds with the concept of SNM, the analysis was extended by additional criteria, considering that a clear distinction between bottom-up and top-down initiation would be inaccurate.[307] Rather, this thesis attempts to understand bottom-up and top-down initiation as a continuum. Therefore, the second criterion *stakeholder participation* assessed the degree to which local actors were involved in the niche development, since they are supposed to play a vital role for the further improvement of the niche.[308]

The assessment of *stakeholder participation* was characterised by multiple overlaps in the way the RECs engaged with niche actors. In all cases except for Helsinki and Tongli, stakeholders were given the opportunity to actively participate in the niche development. Workshops as a tool for knowledge transfer were particularly emphasised throughout Murau, Jühnde and Shaanxi, empowering residents to assume responsibilities in local energy generation as *prosumers*. In Shaanxi, rural households, particularly female family members were educated to operate their own biogas plants. Güssing spent much effort in institutionalising knowledge

[307] Heilmann 2008b, p. 10.
[308] Geels and Schot 2007, p. 400.

transfer by founding a *Solar School* and an expert centre. In Jühnde, residents were invited to participate in a large variety of activities, ranging from planning workshops to social activities. The support of residents was especially vital in Feldheim, where the construction of the new grid substantially depended on the financial contribution of local households. The local population was in turn rewarded with a broad range of sponsored social activities. Such forms of stakeholder engagement substantially increased acceptance of the expansion of RE in all of the afore-mentioned RECs.

The significance of sufficient room for stakeholder participation is particularly reflected by Helsinki, where the involvement of residents in the design of *Eco-Viikki* was not emphasised as much. Although some residents had the opportunity to realise own building concepts, workshops for knowledge dissemination were primarily targeted at experts. Improper maintenance of solar installations and mixed feedback from residents hence indicate that the crucial target group, i.e. local niche actors, was clearly missed. In Tongli, explicit accounts of the extent to which residents can actively shape the design of TNET are lacking, since existing news reports focus on the role of the relevant government bodies. The only indications of active stakeholder engagement in the design and development phases come from dena, without according evidence in Chinese documents. In addition, effects of TNET on the local population have to materialise yet, since the project is still under construction. However, TNET attempts to preserve traditional symbols such as ovens by providing clean coal, and a dialogue between a local netizen and a service platform shows that the developers of TNET are generally responsive to stakeholder feedback.

The third criterion *government influence* in turn evaluated the extent to which government representatives participated in the niche development, again, to grasp potential indicators for SNM. The findings are then summarised and analysed in the fourth criterion, *function of the niche*. In this criterion, the four phases of niche development laid out by Geels (2004) were used as a heuristic to determine if the RECs had emerged through niche development or SNM. The role of higher official bodies such as ministries and government agencies in the European cases was mostly limited to funding, e.g. in Güssing and Jühnde. Analogously, the Shaanxi *Sunflower Project* received financial support from provincial authorities and agencies. In addition, when necessary, village authorities assumed the responsibility to select recipients. In the cases of Freiburg and Jühnde, the municipalities were involved in the design and supervision of the respective implementation processes. The municipality of Freiburg particularly supported the expansion of energy-saving technologies, while imposing effective insulation and energy efficiency standards at the same time.

Three cases stood out with a higher degree of government influence. In the case of Feldheim, the German Federal Government had to step in to adapt the regulatory framework, as the village lacked appropriate ownership laws for its independent grid. This intervention was not intended and may thus be regarded as an exception, whereas the RECs in Helsinki and Tongli showed intentionally strong government involvement from the beginning. Eco-Viikki was established on order of the Finnish Ministry of Environment and an association of Finnish architects, while the design and implementation of this pilot experiment were executed by the municipality of Helsinki. In addition, it was largely sponsored by both the relevant ministry and Tekes, the national funding agency. The government's tight control of the project development was also reflected by the fact that a third of the plot area belonged to the state. Similar to Eco-Viikki, TNET was selected by the local government on order of government ministries and the NDRC, which asked for the establishment of 'unique towns', while the town takes part in a broader experimentation zone and a pilot project for low-carbon provinces and cities at the same time. Supported by the NEA and in collaboration with the municipality, two subsidiaries of State Grid play leading roles for the construction of TNET. The predominant role of government bodies in both Eco-Viikki and TNET are further indications for SNM, implications of which will be highlighted in the fourth criteria, *function of the niche*.

As a summary of the three previous criteria, the criterion *function of the niche* also serves as a proxy to determine if the respective RECs were predominantly characterised by innate niche dynamics in the sense of the MLP or if they were a result of SNM. Therefore, this criterion referred to the four phases of niche development introduced in chapter 2.1.3, which allowed evaluation of the evidence for MLP and SNM in light of successful project completion, based on the premise that success is measured by the complete replacement of the dominant but non-renewable energy systems through RE. Results from this evaluation are summarized in **Table 9**.

Table 9 Niche development phases in the European and Chinese RECs. (Own table)

	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Graz	X	X		
Güssing	X	X	(X)	X
Feldheim	X	X	n.a.	X
Freiburg	X	X		
Helsinki		(X)		X
Jühnde		X	(X)	X
Murau		X	(X)	X
Shaanxi	X	X	(X)	X
Tongli		(X)		X

The evaluation concluded with the fact that the majority of selected RECs did not undergo all phases of niche development. Whereas Graz, Güssing, Feldheim, Freiburg and Shaanxi established RECs to respond to local environmental or economic problems, in Helsinki, Jühnde, Murau and Tongli such pilot projects emerged as a result of strategic decisions, either from government bodies or organisations such as energy agencies. Hence, these cases omitted the first development phase.

The second phase was completed by almost all RECs. They saw the emergence of niche community in the second phase of niche development, which assumed the role of expert groups and were responsible for improving the innovation, i.e. the introduction and expansion of RE in their communities. As immediate users of the innovation, niche actors can be particularly helpful for further enhancements of the niche. Although Helsinki evidentially asked experts throughout the design and implementation of Eco-Viikki, the developers failed to integrate the users, i.e. residents of Eco-Viikki. Not only would they have provided valuable feedback for the design of the experimental area, but they would have been crucial for the operation of the installed solar technology. Whereas most RECs offered workshops to local stakeholders, the one-sided knowledge transfer in Eco-Viikki led to inappropriate maintenance of solar installations. As a result, Eco-Viikki was not able to achieve its reduction targets.

Whereas Shaanxi *Sunflower Project* consulted experts to educate rural households how to operate their biogas plants, government institutions related to energy and local subsidiaries of State Grid assumed the role of such expert groups. Without any systematic form of user engagement, however, TNET risks being tailored to official requirements rather than local needs. By providing channels for stakeholder feedback, TNET may be able to avoid mistakes made in Eco-Viikki. The online Q&A feature offered by the Suzhou Convenience Service Centre may serve as a useful basis.

The third phase, in which the innovation improves its competitiveness with regard to price-performance ratio and compatibility with existing technologies, was not fully applicable to the selected sample. This was because government funding for RE makes it unnecessary to enhance the competitiveness inherent to RE in comparison to conventional energy. With its independent energy grid, Feldheim was a particular case which did not have to consider price-performance ratio and technical compatibility of its renewable energy sources, given that the village had no choice but to establish parallel structures. Consequently, this phase fails to capture Feldheim. Yet, hints for economic improvements through RE could be observed in Jühnde, where the costs of RE generation were adapted to price levels of conventional energy, as well as in Güssing, where the introduction of RE itself improved the cost effectiveness for the entire village by cutting its energy expenditures by 50 percent within two years. Nonetheless, some RECs gave impetus for imitations, which is another characteristic for the third phase and which was observed in Murau, Jühnde and Shaanxi. Consequently, these RECs partly completed the third phase. Yet, the fact that none of the RECs were forced to enhance the competitiveness of their installed RE systems lead to the assumption that financial support from government bodies helps to leapfrog the third phase.

The fourth phase is completed if the innovation was able to replace the dominant technology completely, i.e. if the introduction of RE was able to phase out the dominance of fossil fuelled energy entirely. Apart from Graz, Freiburg and Tongli, which are yet to achieve this goal, all selected RECs have become almost 100 percent renewable. Notwithstanding, there were obvious differences between the ways in which the RECs completed this phase, mainly owing to the disparity of niche development in the context of the MLP vs. SNM.

Based on the niche analysis, the cases of Güssing and Shaanxi can be attributed most to the MLP logic of niche development, whereas Helsinki and Tongli show the strongest evidence for SNM. However, while Güssing and Shaanxi underwent all four phases of niche development according to the MLP logic, Helsinki and Tongli were able to omit half of them. Yet, all four RECs completed the fourth phase, replacing fossil fuels in their respective energy mix by almost 100 percent RE. Feldheim, Jühnde and Murau were able to leapfrog parts of the development phases with similar success, with Jühnde and Murau showing partial characteristics of SNM. In response to the criticism of a clear distinction between bottom-up and top-down, this thesis understands the relation between MLP and SNM as a continuum, onto which the selected RECs can be placed (see **Figure 10**). Decisive for the RECs' positions, however, is not the number of fulfilled or omitted niche development phases. Rather, the four phases complement findings from the four criteria analysed before, which play a predominant role in determining if the RECs developed following the MLP logic or SNM, which is reflected in their position on the continuum below.

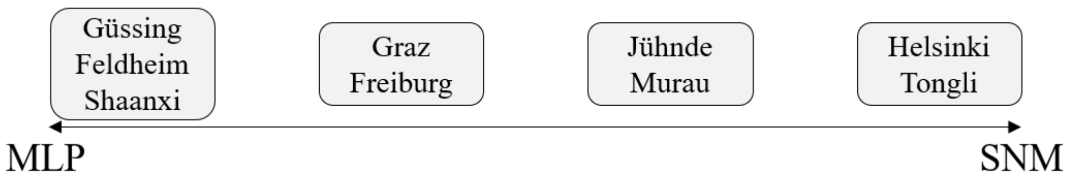

Figure 10 Selected RECs on the continuum of MLP and SNM. (Own illustration)

The analysis of the two Chinese RECs has shown that in the context of sustainability transitions, Chinese RECs do not differ significantly from their European counterparts as initially assumed. Chinese initiatives for 100 percent RE on the niche level have proved to be equally diverse as international RECs with regard to their initiation, design and function. The case of Shaanxi *Sunflower Project* has been particularly surprising, as it falsified the underlying assumption that RECs in China were exclusively selected in a top-down process. Equally valuable was the justified objection that a simple dichotomy of bottom-up and top-down fails to capture the interactivity of Chinese policy-making processes, in which local and central government bodies in fact depend upon each other. From the government perspective, however, the development of RECs must necessarily follow the SNM logic, since grassroots initiatives emerge unpredictably. Implications of this will be discussed in the next chapter.

The application of SNM to initiate local pilot projects in China is further facilitated by the well-established practice of *experimentation under hierarchy*, serving at pretesting policy options before they are scaled up and implemented nationwide. Embedded in a broader experimentation zone and accompanied by supportive government documents, TNET has been identified as a case of SNM. As such, it benefits from political and financial support from government bodies on both the national and local level, which have proved to accelerate the 'traditional' niche development after the MLP. Nevertheless, TNET has the potential to learn from experiences in Shaanxi as well the European RECs, which will be discussed below.

4. Discussion

Theoretical implications

By applying the concepts of MLP and SNM onto the international and Chinese socio-technical energy systems, underpinned with evidence from seven European and two Chinese case studies, this thesis has contributed to a deeper understanding of sustainability transitions, with a focus on the role of RECs as niche experiments. Building upon Heilmann's (2008) insight that a dichotomy of bottom-up and top-down initiation does not sufficiently capture the interactive dynamics between the regime and niche level, this thesis proposes to understand the relationship between MLP and SNM on a continuum. Developing proxy criteria on *initiation*, *stakeholder participation*, *government influence* and *function of the niche* helped to assess if the development of RECs was rather driven by the logic of the MLP or SNM. As a result, this thesis found that a stronger tendency towards MLP hints to the dominance of 'natural' niche dynamics, whereas a stronger tendency towards SNM indicates that strategic calculations were in play. Placing the RECs onto the developed continuum finally proved to be more suitable to comprehend the different relations between bottom-up and top-down, hence verifying Heilmann's (2008) hypothesis.

In addition, comparing the RECs with Geels et al.'s (2004) four phases of niche development allowed for evaluating the differences between MLP and SNM-driven cases in view of their results. Yet, the observations indicate that RECs with signs of SNM omitted at least one niche development phase.[309] Consequently, SNM seems to distort the MLP-based understanding of dynamic niche development, although the target, i.e. becoming almost 100 percent renewable, was met nevertheless. This leads to the assumption that employing elements of SNM, such as financial support from governments and other regime institutions, can help leapfrog phases which would usually involve significant efforts for grassroots initiatives, e.g. for raising funds. Therefore, active government support can safeguard the survival of innovations which would struggle on their own. To determine if this support actually accelerates the development of the

[309] This does not apply to Graz and Freiburg, although they did not undergo all phases either. In their case, this owes to the fact that their path towards 100 percent renewable is yet to be completed.

niches, however, would require further research which takes temporal aspects into account. Implications of this finding will be further discussed in the *practical implications* section below.

The analysis of the *function of the niche* in chapter 3.1.3 has shown that there can be controversy regarding whether or not RECs should be classified as a niche experiment. In this thesis, it was questioned if the RECs of Graz, Freiburg, Jühnde and Murau can be seen as veritable niches, arguing that they were not specifically designed to instigate a broader energy transition but rather to be copied in other regions as well. Nevertheless, this thesis reasons that such RECs, which serve as role models for other regions, cities and communities, can fulfil a valuable multiplier effect, which enables them to gradually build up momentum until they are recognised and taken up on the regime level. Hence, they constitute niches in the sense of this thesis.

Practical implications

Considering that almost all RECs were or will be able to replace fossil fuelled energy with RE in the medium or long-term, this thesis does not assert that one model was better than the other with regard to the effects of MLP or SNM-based niches, as each concept has its advantages and disadvantages.[310] On the one hand, niches emerging from the MLP logic can have significant impact on the energy regime and play a supportive role for the broader energy transition, as demonstrated by the success of Güssing and Shaanxi. As the comparative analysis has shown, stakeholder participation is vital for the success of niches and as a result of grassroots initiative, strong stakeholder participation is inherent to RECs that are based on the MLP logic. On the other hand, such niches emerge unpredictably, supporting the argument that niche development cannot be steered purposefully. The advantage of SNM is that the successful replacement of the existing technology, i.e. fossil fuel-based energy generation, is guaranteed and may even be achieved in a faster pace. Yet, SNM risks to ignore the role of local niche actors, which may be reflected on overall stakeholder satisfaction and potentially impede the entire niche development. However, given that MLP-based niches cannot be induced actively, decision-makers may have no other method to resort to than SNM.

Accordingly, since niches evolve spontaneously in response to local problems following the logic of the MLP (see Shaanxi *Sunflower Project*), they are not calculable from the government perspective. Given that the Chinese central government is interested in promoting a nationwide energy transition to respond to landscape developments which lead to an increased domestic energy demand, it must hence employ means of SNM in order to foster energy transitions in the country's regions, cities and communities. The decentralised nature of distributed energy generation and the sustainability of RE make RECs a viable and promising option for this.

[310] Exceptions are Tongli, which is yet to be completed, as well as the cities of Graz and Freiburg, which aim to become energy self-sufficient in the future but are challenged by their sizes, since they are larger as the other cases.

Consequently, what decision-makers can learn from these indispensable but uncontrollable niches is to put stronger emphasis on stakeholder participation, i.e. to create channels to obtain user feedback and let local niche actors participate actively in the design and implementation of RECs. This information supports the argument that stakeholder participation can and should be planned for in SNM (see chapter 2.1.3). Hence, the case studies analysis proved that although active government support can secure the survival of a niche, a high degree of government influence may fail to adapt the niche innovation to user needs, whereas a high degree of stakeholder participation potentially increases the acceptance of niche actors towards the project. Consequently, a position in the middle of the continuum between MLP and SNM seems most desirable. As shown in **Figure 10** (p. 67), Jühnde and Murau as well as Graz and Freiburg are closest to the position in the middle. While Jühnde and Murau can be seen as viable role models, given that they incorporate both strategic initiation and appropriate means of stakeholder participation, final results for Graz and Freiburg are still pending. Decision-makers who intend to employ SNM for the formation of a new niche are thus advised to create sufficient room for stakeholder participation already in the project design. In doing so, failures as in Helsinki can be avoided.

These insights are particularly valuable for Chinese RECs. Although it is difficult to evaluate TNET at this point in time, given that it is not yet completed and reports on its project design are rather one-sided, local governments and official project developers could plan for appropriate forms of stakeholder participation in pilot experiments ordered by central government authorities. Shaanxi *Sunflower Project* can serve as a valuable example, since the grassroots initiative was able to exploit the potential of comprehensive stakeholder participation while receiving support from local government bodies and agencies as well. As a result, the project was rewarded with a high degree of acceptance among local niche actors. Analogously, sound and comprehensive stakeholder management in Tongli could raise acceptance and satisfaction from local stakeholders towards TNET. This is not only crucial because niches can benefit from users and their experiences, but also because stakeholder resistance has been identified as a significant obstacle for niche development in the regime analysis.

In addition, Chinese decision-makers could take measures to reduce the influence of incumbent regime actors. As the regime analysis has shown, the Chinese energy market is largely dominated by State Grid and its provincial subsidiaries, and the establishment of TNET has proved that these monopolies play a crucial role in the development of RECs as well. However, the third strategy of SNM advises limiting the influence of incumbent players in the regime. In doing so, decision-makers could prevent vested interests of large grid operators from impeding the expansion of distributed energy.

Limitations and implications for further research

Owing to different reasons, the findings of this thesis are to be treated with care. Firstly, although the multi-case report is based on a diverse set of sources such as academic articles, as well as online reports and news, information on the selected cases is largely drawn from case study reports. As the comparative analysis relies on sources dating back to 2010–2014, apart from TNET, this thesis may have overlooked RECs which may have evolved in recent years. In addition, since all cases except for TNET have been analysed in retrospect, the findings cannot make any statements about more current results, nor can they compare the results with more recent RECs. These constraints can be explained with the limited scope of this thesis.

For the same reason, the analysis of the landscape and regime levels may not accurately describe relevant influences on the selected RECs, since drivers and elements of the energy systems may have been different at the time when the case studies had been carried out. Nevertheless, since developments on the landscape level are changing slowly, trends such as climate change and urbanisation have not lost their relevance but have rather become ever more important. Similarly, decentralisation and distributed energy generation continue to be the main regime drivers for the energy transition. Hence, drivers and elements on the landscape and regime level have largely stayed the same. Nevertheless, future research may employ a retrospective when analysing socio-technical systems.

The comparison of the different cases was further impeded by the varying scope of the RECs, which made it difficult to classify them appropriately with the niche-regime dichotomy. While some RECs were limited to villages, others covered entire cities or regions. A particular case was the Shaanxi *Sunflower Project*, which acted on the village-level but at the same time spanned several villages within Shaanxi province.

Throughout the niche analysis, the criterion *government influence* has proved to require further adaptation. Although it provided valuable information about the extent to which government support can help RECs leapfrog certain phases of niche development, a criterion focusing on *governance* would have been able to better grasp the different actors behind the selection and initiation of RECs.

Having proved that SNM plays a crucial role in many RECs internationally, future research may investigate methods to optimise the design of such niches. For this purpose, researchers may also consider the clear parallels between SNM and *experimentation under hierarchy* and attempt to exploit potential synergies of an approach which takes both concepts into account. Seeing pilot experiments in the context of SNM is particularly valuable for analysing the governance of related pilot projects in the China, yet theories related to the MLP and SNM have not yet been reflected in relevant Chinese literature. In addition, based on the hypothesis that RECs should aim to reach the middle of the continuum, further research may explore practical measures to realise such an MLP-SNM equilibrium.

5. Conclusion

Worldwide, there is an increasing number of RECs, i.e. regions, cities and communities, which are either on their way to an almost entirely renewable energy mix or have already achieved it. Chinese government bodies have pledged to support the expansion of RECs as well. Hence, this thesis aimed to comprehend motivations for nations to engage in the promotion of RECs and highlight possibilities to do so, while focusing specifically on China's ambitions, with the assumption that Chinese RECs are initiated top-down as pilot experiments. For this purpose, this thesis adopted two frameworks within the field of sustainability transitions. The MLP describes the dynamic evolution of niches and how they permeate the energy regime, while SNM explores how niches can be established and managed strategically. These frameworks were applied to a heterogeneous set of European and Chinese RECs and adapted to allow for their systematic comparison.

Similar to other countries, arguments for China's motivation to promote RECs were found in megatrends on the landscape level, such as urbanisation, digitalisation, resource scarcity, climate change and environmental pollution, all of which result in an increasing energy demand. This pressure was reinforced by unfavourable regime elements, such as the country's substantial dependence on foreign fuel imports.

To solve these challenges, transitioning to a cleaner domestic energy system is imperative. While the international cases employed varying methods related to SNM, next to niches which emerged on grassroots initiative, the Chinese government employs niche experimentation and it strategically selects locations for pilot projects. These serve to pre-test policy options before choosing those that are suited for a nationwide dissemination. As the case study on TNET has shown, RECs fulfil an experimental role in the broader Chinese energy transition, which corresponds to the concept of SNM at the same time. Simultaneously, grassroots initiatives from China's civil society can emerge on the niche level and gradually build up momentum as supported by the MLP. This form of dynamic niche development was observed in the case of Shaanxi *Sunflower Project*, which had started on the village level, until it gradually expanded over Shaanxi province. Hence, evidence is supported by both the MLP and SNM, rejecting the assumption that Chinese RECs follow the SNM approach exclusively.

In addition, analysing the respective RECs with regard to *initiation*, *stakeholder participation*, *government influence* and *function of the niche* revealed valuable learnings, which are relevant for Chinese RECs as well. Firstly, reasons for the *initiation* of RECs could either be the urge for RE to solve local environmental or economic problems or strategic selection with the aim to realise political decisions on higher administrative levels or to explore the technical feasibility of certain technologies. Secondly, the analysis of *stakeholder participation* showed that generally, RECs with stronger emphasis on user feedback and stakeholder participation were rewarded with higher acceptance, while the case of Helsinki indicated that insufficient room for stakeholder participation can negatively affect the overall success of the project. Consequently, appropriate channels for stakeholder participation can be seen as crucial success factor for RECs. Thirdly, with regard to *government influence*, financial support has proved viable to secure the survival of the RECs. However, government influence should not be over-emphasised to sustain a sound balance between stakeholder participation and government influence. The last criterion *function of the niche* determined the degree to which the logic of the MLP or SNM dominated the respective RECs. It concluded with the finding that a stronger MLP orientation corresponded with 'natural' niche dynamics, while a stronger SNM orientation hinted to strategic calculations behind the niche development.

Both concepts have shown to be suited for the transition to 100 percent RE, but an over-emphasis on SNM risks to neglect stakeholder needs and may cause resistance. Although an MLP-driven niche development bears the potential for higher stakeholder acceptance, the emergence of such niches is not controllable, which is why policy-makers have to resort to SNM. Putting stronger emphasis on stakeholder participation throughout SNM may mitigate this risk, as the cases of Jühnde and Murau have demonstrated.

Accordingly, recommendations for Chinese and international decision-makers alike include efforts to ensure a balanced relationship between stakeholder participation and government influence. This also includes limiting the dominance of incumbent actors in the energy regime, such as large state-owned utilities. Acknowledging that grassroots RECs such as Shaanxi *Sunflower Project* emerge spontaneously and are thus not controllable, project designs based on SNM could incorporate stronger emphasis on stakeholder participation. Online channels for user feedback as offered in the case of Tongli serve as a useful basis.

This thesis did not only contribute to a deeper understanding of the role of RECs in the context of the energy transition, but also added to conceptualising the relationship between the concepts of MLP and SNM. Based on in-depth analysis, this relationship is finally understood as a continuum ranging from MLP to SNM, allowing for are more differentiated understanding of bottom-up and top-down. The application of this continuum to the selected cases resulted in the conclusion, that an REC design which balances stakeholder participation and government influences is most desirable. In addition, this thesis identified clear parallels between the concept of SNM and *experimentation under hierarchy*. Future research could build upon the findings of this thesis by investigating possibilities to realise such a balanced REC design, as well as by including case studies from other parts of the world and applying a retrospective when analysing cases that have already been completed.

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Ich erkläre, dass das Thema dieser Arbeit nicht identisch ist mit dem Thema einer von mir bereits für ein anderes Examen eingereichten Arbeit. Ich erkläre weiterhin, dass ich die Arbeit nicht bereits an einer anderen Hochschule zur Erlangung eines akademischen Grades eingereicht habe.

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Ort, Datum

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