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Moving towards Energy Self-Sufficiency Based on Renewables: Comparative Case Studies on the Emergence of Regional Processes of Socio-Technical Change in Germany

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Abstract: The change of conventional energy systems to a system mainly based on renewable energies is occurring in many parts of the world. A processual analysis of three case studies from regions in Germany that are moving towards renewable energy self-sufficiency were conducted in order to better understand this process of socio-technical change. This paper scrutinizes the role of actors and their activities, which are driving the change of the local energy system. Three discrete distinguishable phases of this change were found: pioneer phase, pivotal network phase, and extended network and emerging market dynamic phase. Each phase can be characterized by the type of actor, their specific activities, artifacts involved, and their underlying motives. We suggest using the phase model as a heuristic instrument to identify the elements which shape socio-technical change.

Keywords: socio-technical change; energy system based on renewable energy; renewable energy; phase model; processual analysis

1. Introduction

The idea of changing from conventional energy systems to a system mainly based on renewable energies is currently being discussed on national, European and global levels [1]. Although some documents that provide guidance on how to implement this vision do exist (for example, [2–5])

controversy persists regarding the best way to reach this objective, especially in terms of making concrete decisions, investments, and practices. Nevertheless, in many regions and local municipalities in Germany, concrete efforts to move local energy systems towards a system with greater renewable energy content can already be identified. An increasing number of these regions have even committed to the goal of reaching energy self-sufficiency based on renewable resources. As a result of this dedication and their increasing experiences, these regions have assumed a pioneering role in the process of change [6–8].

The continuously rising number of regions aiming for renewable energy self-sufficiency is an interesting phenomenon that needs to be explained. While there are many arguments given for it in the political arena—enhanced local value creation by decentralizing energy supply systems via regional and local self-governance processes—to our knowledge (and as we will show in the following section) there is a lack of studies that aim to understand the regional socio-technical process of changing energy systems as a whole. This is the case as most studies focus on single subject aspects or are of conceptual and theoretical nature (see Section 2).

In this paper, two salient questions are posed: First, how do regional processes of change towards a new local energy system based on renewable energies emerge? Second, how do these processes evolve over time to achieve the goal of renewable energy self-sufficiency (RESS)? To avoid the domination of one theory as “the only model in town” related to the phenomenon of socio-technical change [9], we have employed an inductive research approach, asking the above questions, in order to understand what happened in the regions. In a second step, we have identified important elements that can help to analyze the regional process of social-technical change. Based on that, in a third step, we discuss starting points for future research related to the identified elements that we found helpful to understand socio-technical change in our cases.

The paper is structured as follows: In Section 2 we try to locate our research in the existing research landscape. In Section 3, the method is explained and results are presented in Section 4. We have identified three distinct phases within the process of socio-technical change. Each phase can be characterized by the type of actors involved and their specific activities. Following this logic, we labeled the phases “pioneer phase”, “pivotal network phase”, and “extended network and growing market phase”. In Section 5, these results are compared to the state of knowledge. Our contribution is not seen as a theory, but as a heuristic that helps to structure the phenomenon of socio-technical change. This is done in order to identify starting points for future research.

2. Positioning and Starting Point of Our Research

Following Geels [10], a process of change (In the literature, the change of socio-technical systems is often labeled as transition [11] and [12] or transformation [13]. These notions already imply a specific quality of the change [14], describing the goal in which the change is tending toward and the degree to which the existing state is changed. The goal and the degree can only be determined retrospectively. The notion of change, in contrast, describes only a difference between states over time (that can occur as a process both incrementally or radically). Due to this, we chose the notion of change because it is more neutral and, therefore, more adequate when referring to an open process of change that is still ongoing.) in a system can be labeled “socio-technical” if the change takes place in

both the technological and social realms and technologies, markets, policy, cultural meaning and perceptions are closely connected to each other. In the discussion about changes of socio-technical systems, a particularly relevant approach amongst existing research approaches is the multi-level perspective (MLP) [10,14]. In this perspective, system innovations, such as a new energy system that is based on a new energy source, are the result of the “interplay between processes at different levels in different phases” [14]. Geels and Kemp [14] argue that the sources of radical change emerge in niches and then can break through and change the overall socio-technical system. Although the MLP is one of the dominant models for understanding socio-technical change, it does not claim to be a comprehensive theory, taking also into account that several approaches like e.g., large technical systems (LTS) [15,16], technological systems [17,18], sectoral systems of innovation [19,20] or transition management [21,22] are scrutinizing socio-technical change with a slightly different focus. The discussion regarding the appropriate theory for explaining socio-technical change is still taking place [11]. In this sense, this research paper does not favor one theory, but instead wishes to deduce, based on empirical data heuristics, one that can be used as a starting point for further discussion regarding theory building. Through the avoidance of one dominant theory [9], the focus is placed on particular aspects of this multifaceted phenomenon and not on a single theory.

Other studies focusing on the empirical phenomenon of the process of change in the energy system have analyzed specific aspects and evaluated them in relation to their contribution to the process of change in the energy system. For example, the importance of a “guiding vision” enveloped in the term of “energy regions” is described. Such visions hold the potential to align actors from different governance levels [23]. Other aspects are actors and networks. Several projects have investigated the role of actors and networks within the change of an energy system, focusing on the transformation of the electricity system (for example, Beck *et al.* [24] in the case of South Africa). Praetorius *et al.* [25], for instance, analyzed the role and influence of actors, networks, and political instruments for the emergence of five different kinds of innovations, focusing on technological systems instead of regions. Among other things, they identify phases of the innovation process, but do not relate the actors and their roles to these phases. Kratz [26] scrutinizes the role of renewable energy networks as related to different regional projects and initiatives and identifies the conditions necessary to shape positive conditions for the involved actors in these projects. There are also other examples in the literature that describe the creation of regional actor networks for renewable energy regions (e.g., [27]). These works share an emphasis on actors and their networks as drivers of the process of change. They do not encompass, however, more detailed analysis on the exact role of networks and actors that go beyond the general recognition of the significance of these drivers for the process.

In the existing stated literature on the empirical phenomenon of the process of change in the energy system, different individual aspects of the process of change, such as guiding vision, actors or networks, are rarely combined in order to gain an understanding of their interaction within the process, nor are they used to develop a broader model of change [28]. An exception is the work of Mårtensson and Westerberg [29], who identified the following three sub-processes of an emerging strategy to move local energy systems toward bioenergy: problem formulation, mobilization, and communication. However, their primary focus is not the process of change itself, but to identify the strategies for municipal authorities that are helpful to initiate and manage local processes of change. The same holds true for the conceptual framework presented by Müller *et al.* [30]. They developed a roadmap for implementing

renewable energy self-sufficiency in a region, which is defined by the steps: initialization and preparation, analysis, strategic decisions, planning, implementation, and monitoring and evaluation. Within these five steps, different aspects are highlighted. Their concept is, however, not based on empirical work, and is rather meant to be a tool to assist administrations and civil society actors when organizing an energy transformation process in their region. Another example of combining aspects is the project “The Bio Energy Village”; here, scientists analyzed, among other aspects, social implementation, technical concepts, and ecologically sound cultivation concepts for energy crops. The objective of the project was to transform the local energy system of one village, based on heat and electricity, into one run completely on biomass [4,31].

Altogether, the stated literature regards different aspects of the emergence of the process of change and first approaches can be found that tried to develop models that support the change of the energy system. The stated efforts, however, are far from developing a theoretical understanding of the regional transformation process. Due to the lack of an all-embracing theory for the process of change and that an ongoing discussion is being had about an appropriate theory, an inductive approach guided by different aspects of the phenomenon could help to produce new theoretical insights; and thus valuable starting points for future research [32].

3. Method and Cases

In this paper, we employ such an explorative inductive research design for the analysis of emerging regional energy transformation processes. Hence, we are interested in understanding the process of change not based on a certain theoretical concept or reduced to a specific focus, but in describing important elements and triggers of the process based on empirical fieldwork (*i.e.*, on the perspectives of the involved actors). Following van de Ven [33] we understood a process as a “sequence of events that describes how things change over time”. This encompasses “a sequence of individual and collective events, actions, and activities unfolding over time in context” [34]. Events can be regarded as certain points in time where important changes are instigated. They are created by humans through their actions. In a series of events, actors have the ability to make a difference within the given environmental conditions; they are facing a “pool of opportunities, resources, facilities” which they can use to shape the process [35]. Choosing an inductive research design we began our research on the process of change without formalizing any presumptions about the events, the types of actors, or activities, and did not draw on a specific theoretical framework in order to allow us to be open to unforeseen aspects.

We used a case study approach and combined it with insights from authors working with process data ([34,36–39]). The research followed a multi-case design, allowing for “replication” logic. Comparing the cases with one another helped us to identify differences and subtle similarities [36]. Therefore, every case was treated as an experiment that can confirm or reject the undertaken observations [38]. This approach allowed us to filter out what was specific to a region and to discover generalities between the cases.

As cases for the study, we selected two administrative districts and one municipality in Germany, that were seen as being at the forefront of the process of change towards renewable energy systems: These are the administrative districts of Lüchow-Dannenberg and Schwäbisch Hall and the municipality Morbach. Hence, these cases are delineated by their administrative boundaries (administrative districts

and municipalities) (The administrative district is at an intermediate level of administration between the German States (“Länder” in German) and the municipal levels. A district is governed by the district council and the “Landrat” who administers the district. Municipality (“Gemeinde” in German) refers to a single settlement that is governed by a mayor and the local council. Text we will refer to regions comprising both types of areas.).

The district of Lüchow-Dannenberg is located in the north of Germany. It is one of the most sparsely populated districts in Germany with about 50,000 inhabitants and an area of 1,220 km². The district is economically weak and characterized as being mainly agricultural. The district of Schwäbisch Hall is in the south of Germany and has about 190,000 inhabitants. It covers an area of 1,480 km². The economy is based heavily on the engineering industry and is well-known for its animal breeding. The municipality of Morbach is in the west of Germany. It has about 10,500 inhabitants in an area of 122 km². Different companies are located in Morbach, which gives the municipality a sound economic structure.

These cases were identified by conducting a pre-study [6]. In this study, we identified administrative districts/municipalities across Germany that met the following selection criteria: existence of a political commitment towards the target of reaching renewable energy self-sufficiency and a share of renewable energy in the local energy mix greater than Germany’s average. Amongst those regions, we selected three regions for in-depth analysis that were notably distinct from each other regarding the number of inhabitants, landscape structure, socio-economic conditions, and local culture. These different contexts of the chosen cases were meant to provide us with a better opportunity to identify factors that were of general importance to the process of change in all regions, in comparison to factors that were only important in a specific regional setting.

3.1. Data Collection

We used 55 semi-structured interviews with so-called key actors in the three regions as the primary data source. In line with our inductive approach, we strived to identify these key actors in an empirical way. We began by conducting a document analysis of regional energy reports from the regions and asking employees of institutions related to the energy issue within the regions to name actors in their region decisive to the process of change. *Snowball sampling* was used: That is, we started our interviews with actors we identified as being central based on document analysis, and asked them to name, from their point of view, the most influential actors within the process of change. We also asked the actors to identify the individuals they interacted with during the process in order to draw up a focal network for every key actor. The key actors we contacted belonged to very different groups within society, including entrepreneurs, managers, mayors, employees of the administration, and members of citizens’ initiatives.

The interviews lasted an average of about 60 min. They were conducted in the field, where the interviewer visited the interviewees at his or her place of work, except for five interviews that were conducted per telephone as we could not meet these actors during our fieldwork in their regions. The interviews were carried out based on an interview guide, beginning with an open question, which gave the informant the possibility to express his own experiences related to the process. The main influence of the interviewer was to encourage the interviewee to concentrate their answer on events and aspects they deemed important from their point of view. As an anchor point for the respondents, we choose the

political adoption of the target of reaching renewable energy self-sufficiency within the region and events related to the process of change we already identified in the preceding interviews. The informants were also asked to describe their own activities related to the process and any exogenous factors influencing the process.

3.2. Data Analysis

The start of the analysis was typical for inductive research in that it built individual case studies for each region in order to construct a conceptual framework [36]. The recorded interviews were all transcribed and synthesized with related documents like newspaper, internet homepages, and archival data to construct a case history. This additional information was used to enrich and to reflect the statements given by the interviewees. As the interviews were conducted by two interviewers, the single interviews were analyzed by the interviewer that hadn't conducted the interview to avoid pre-framing of the text. This analysis process gave us the opportunity to interpret the texts and the following cases from two perspectives.

The first step was to develop a chronological listing of the events that were labeled as being important by the interview partners for the regional process of change. Among the interviewees, there was typically a high level of agreement about decisive events. The events served as a guideline to write the emerging history for each case. For the next step, every decisive event was enriched by information from the texts and documents, and activities that linked the events to a continuum were detected. The third step in organizing the process data was coding the events into different tracks [40].

A track is defined by one element that can be identified as a part of the process. As a track, the element is trailed through the course of time. The tracked elements constituted together associate the process. The tracks were formed in an iterative manner: First, the tracks were defined by elements that were part of our stated understanding of a process, such as actors. Then, in interaction with the collected data base, new tracks defined by new elements were formed, old ones were abandoned; until tracks emerged that correspond to the process found in all three cases. For example, we initially distinguished an actors-track, containing single key actors and groups involved within an event where specific activities were performed at a given point in time; through their activities the actors formed informal and formal relationships between the different key actors and groups. The relationships observed were, at first, assigned to a relation-track, which was, at the end of the analysis process, subsumed to the *actors-activities-track*. The drawing of an ego network related to the key actors and a data matrix helped us to structure the relationship between the different actors in the time flow and, regarding the actors-track, to evaluate the importance of the actors for the process.

Furthermore, we distinguished at the end, a *motive-track* in which the main motivations and goals driving the identified key actors within the regional process of change were identified, and an *artifact-track*, in which the different technological and political invention and products that were patterning the process, related to the different key actors and groups were observed.

Parallel to patterning the tracks in the process of change within the region, we constructed an overall context of developments which were located outside of the region and the realm of the actors, but which had, following the statements of the respondents, an effect on their own activities and thus on the process of change. We called it the *wider-context-track* in which the regional transformation

process was embedded. During the research process we distinguished two manifestations of the *wider-context-track*, a geographical context and an institutional context. The geographical wider-context contained actors and their activities, and with whom actors had contact in relation to the process of change. We delineated the geographical boundary specific to the administrative boundaries. The institutional wider-context included institutional settings (like laws) or national wide developments that were perceived by the actors as having a direct influence on their activities. The institutional wider-context could differ from case to case thus a regionally specific institutional wider-context could be identified. Interpreted in this way, the wider context was seen as a necessary way to delineate the boundaries of the cases in which relevant elements like actors and their activities, artifacts, motives, and their association could be scrutinized. The element of a wider context serves as a technique to reduce the complexity found in reality and to delineate the boundaries of the research object, thus focusing our efforts on the regional process of change and its connection to the wider context.

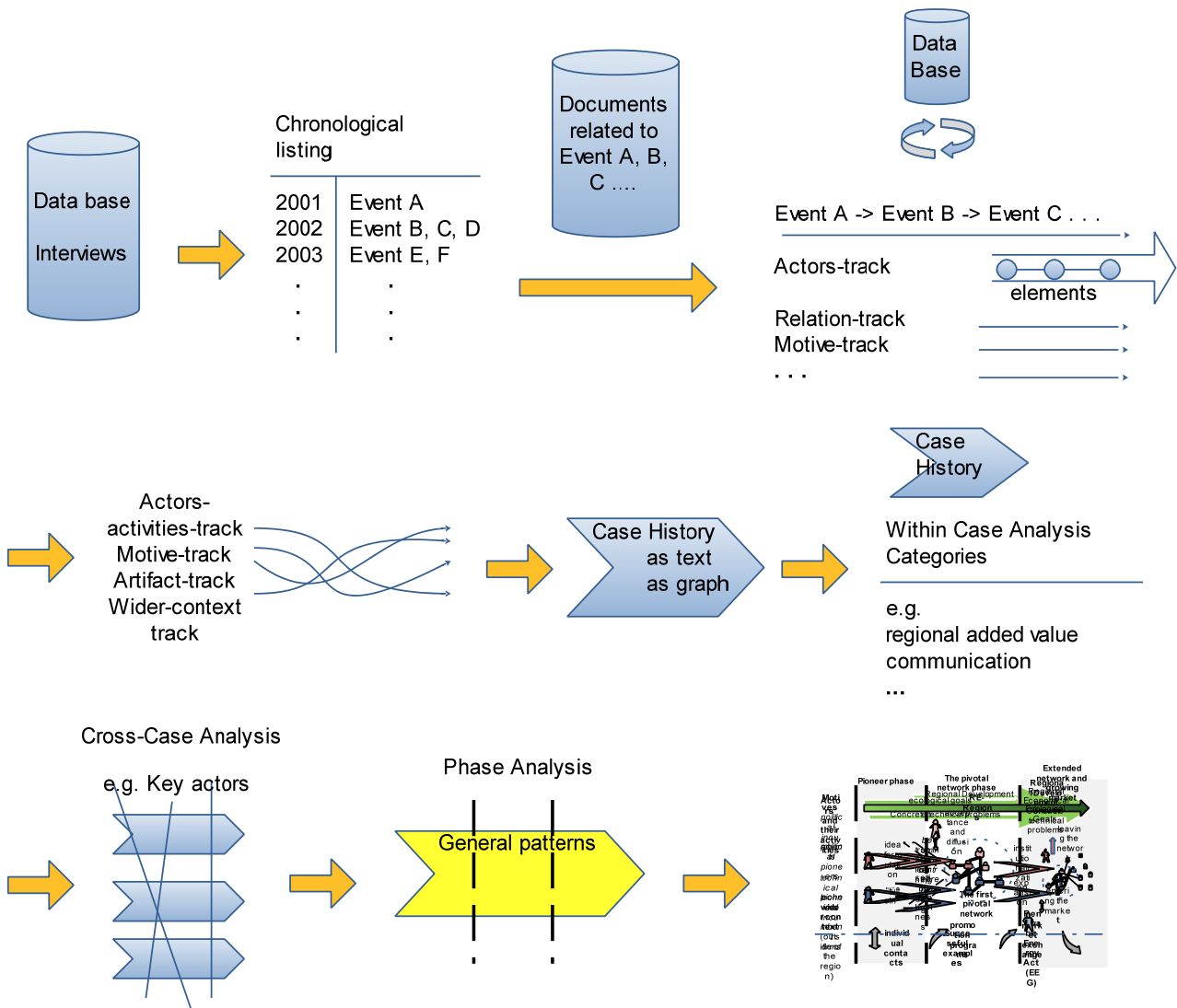
In the end, four tracks were identified and labeled as an actors-activities-track, a motive-track, an artifact-track and a wider-context-track. The process was not perceived as a single stream, but instead more like a river basin where there are several streams, the different tracks, all flowing into another to finally form one process [34].

To convert a case history into a case study, two types of analysis were conducted within-each-case and cross-case, with the aim to search for patterns in the process and to find underlying mechanisms “which shape any patterning in the observed processes” [34]. For the within-each-case analysis, categories were formed, which were initially related to the different tracks, for example the category “communication” was assigned to the *actors-activities-track* and “regional added value/ regional development” to the *motive-track*. Other categories emerged while working with the texts. The new categories were added to the analysis and applied to all of the texts. The analysis proceeded in an iterative process in which specific categories were refined and the analysis continued in more detail.

After becoming familiar with the single cases, we started the cross-case analysis (see a summary of the tracks in Table I in the appendix). By analyzing the categories, we searched for similarities and differences between the cases [36]. While there were differences related to the local contexts regarding the process of change, similar patterns consisting of similar elements emerged. Another technique applied was graphical representation. Graphs effectively presented the case histories in a visual form. The visual mapping strategy allowed us to compress the data onto a single sheet, thus facilitating comparisons by enabling the simultaneous presentation of parallel sub-processes and the passage of time [39]. The emerging process patterns were refined by applying the replication logic. We verified the single elements of the process by revisiting them if any formed a part of the process in the other cases.

To reduce the complexity of the emerging elements patterning the process, we used a further technique called phase analysis, consisting of identifying discrete phases of change activities [40]. A phase is a period of unified and coherent activity implemented by specific actors that drive the process [40]. In order to construct the phases, we used at first the actor constellations that dominated the process for a period of time through their activities. Then, related to the actors, the other three tracks (motives, artifacts, wider-context) were associated to define the phase. The methodical procedure is summarized in Figure 1.

Figure 1. Methodical procedure.



4. The Process of Change

Three phases emerged during the data analysis: the pioneer phase, the pivotal network phase and the extended network phase, accompanied by a growing market. For the delineation of the phases we identified three elements: (1) the actors and their activities; (2) the role of motives; and (3) the role of artifacts, as well as the role of the geographical and institutional wider-context, in which the three elements are nested. These elements mainly impacted the activities and the characterization of the governance process as a bottom-up or top-down process. In Table 1, typical citations representing the phases are listed. In what follows, the phases will be described in detail, including references to literature on socio-technical change.

Table 1. Typical citations for the process of change (not complete).

Phase	Citation
Pioneer phase	
<i>A farmer pictures the work of the technical pioneers</i>	“The development of biogas, of course, during its preliminary stages, started out small. Back then we had five plants, really pioneer facilities, and I would like to mention [name of a pioneer] here. At the beginning of the 1990s, he was fiddling and trying to build a biogas plant together with a heating mechanic and an electrician. He was working with smaller systems in mind, starting with 100 kW and from there he went on. These were the beginnings.” (Farmer)
<i>A political pioneer describes his motive for his engagement in the process</i>	“Yes, after I discovered renewable energies, it was clear to me that this is something I had to throw myself into. It is a very important sphere, in the end it is probably one of the central challenges for the survival of mankind because the energy question is reaching into so many other areas. It is not only about energy production but also about the water problem, it is touching the climate and nutrition questions—it is probably one of the central questions of mankind.” (Political Pioneer)
Pivotal network phase	
<i>A political pioneer explains how a political incumbent was joining the process</i>	“Of course, he had a vested political interest that a change in administration would happen during his time but also in the political bodies. That one could say “this has changed and that has happened” or “we are going in that direction”. And he strongly supported that.” (Political Pioneer)
<i>A political pioneer describes the importance of the motive of regional development</i>	“And in the beginning it was always important to mention the economical aspects which are important for districts with high unemployment rates, structural problems, and so on. [...] It doesn't work to only mention that we are green and awesome and we are wearing a saint's halo, but layout all the various aspects to consider, also economical, that we can offer the district and the people in the region.” (Political pioneer)
Extended network and emerging market dynamic phase	
<i>A member of the Biogas Association characterize the significance of the EEG as an important change in the wider context</i>	“One has to say that with the introduction of the Renewable Energy Act [EEG] in the year 2003 it was in 2004 that things quieted and people said, “yes, that is profitable now and even photovoltaic systems pay off” and then they all jumped on. The administrative district jumped on and invested and the energy centre was founded in [name of the district] where PV systems were invested in. And today, the yields of the photovoltaic systems are the foundation for the financing of the energy centre, the administrative district has massively invested there.” (Biogas association)
<i>A member of the administration depicts how the pioneers become successful enterprises</i>	“...so there are really a lot of large enterprises, which, in 2003, when examined retrospectively, were rather small, out of your garage type of business, maybe even laughed at. Today many of these companies are really large, perhaps because they bet on the right horse.” (Administration)

4.1. Pioneer Phase

The pioneer phase of the emerging regional process of socio-technical change was shaped by the activities of single actors that initiated different types of innovative projects related to renewable

energy. Because their activities were perceived as new or radical, often with negative connotations, they were often labeled by the other inhabitants of the region as “eco weirdos”. We called these actors *pioneers* emphasizing the perceived innovative character of their activities. This particular position provided an opportunity for the pioneers to introduce new ideas related to energy and demand responses from the incumbent actors in the region (see [41] and [42]).

From their innovative projects, two main types of pioneers were identified and which we named technical and political. The technical pioneers actively sought to find new technical solutions for the production of energy within their personal settings. In Schwäbisch Hall (SHA) for example, farmers constructed a prototype of a biogas plant that utilized waste as basic raw material for the production of energy. In this case, not only the technology had an innovative character, but also the chosen business model because it was the first biogas plant in Germany established by a cooperative. Also, other farmers in the region, especially those related to the organic farming milieu started to experiment with technologies for biomass-to-energy conversion. Other pioneers, however, built wind mills and promoted hydro power in the region. This was similar to the activities of pioneers in the region Lüchow-Dannenberg (Lü-Da). There for example, a farmer together with a mechanic invented an engine in their garage that was supplied with biogas. Another actor constructed a prototype of a combined heat and power plant, an engineer invented the first dry fermentation biogas plant and the first solar heating panels were installed on roofs. In Morbach, a type of technical pioneer was missing apart from a farmer who was utilizing an oil press to extract oil from rapeseeds to fuel his tractor. But close to Morbach two pioneers could be identified that were installing the first wind mills in the region. Later, in the second phase these two pioneers became relevant for the process of change within Morbach.

To summarize, it can be stated that technical pioneers were often farmers who used and/or developed new technologies for biomass-to-energy conversion in order to supply enough energy to their own farms. Subsequently, these techniques mainly developed and expanded the biogas sector. The pioneers also promoted technologies in wind and solar energy, while activities in the sectors of water and geothermal energy were found only rarely in the regions. However, not all initiatives were successful. For example, the installation of wind mills in Lü-Da or Morbach failed during this time.

The technical pioneers pursued the development of these new technologies, though unprofitable, because they wanted to find practical solutions for their own supply and/or develop new technology as an opportunity for the ecological production of energy in their region. The ecological motive was especially relevant for the farmers in SHA and Lü-Da because they belonged to the organic farming milieu. Furthermore the efforts to find ways to utilize biomass for the production of energy was perceived by the farmers as a responds to the crisis in the agricultural sector in Germany characterized by decreasing prices for agricultural products. Since the technical pioneers’ main motives were not to place a new technology on the market, it may be more appropriate to refer to this activity as *invention* rather than *innovation* [43]. Their activities were concentrated on refining new technologies, an activity that is better represented by the German term “tüfteln”, or otherwise said, tinkering with a design in order to improve it. They were not acting as part of a bigger plan, but instead by improvising and advancing their experiments through trial and error.

Political pioneers, on the other hand, were not primarily engaged in creating a technological project, but in introducing the idea of the expansion of renewable energy (RE) into the local discourse and in relation to a concrete object. In Lü-Da, the political pioneers were participants in the local Agenda 21

group and created the idea of renewable energy self-sufficiency enveloped in the term “renewable energy region” to demonstrate the vision of a future energy system without the use of nuclear energy. They decided to formulate a resolution linked to the idea of renewable energy self-sufficiency (RESS) that would be filed in the regional parliament. In Lü-Da, the discussion surrounding the future role of nuclear power within the energy system was concrete, because the national radioactive waste storage facility for Germany is located within the region. In Morbach, the discussion was about the future utilization of a former military area. While the regional parliament favored the establishment of a leisure park, the identified pioneers were against this proposal and instead wished to promote a utilization of the area that added value to the region in an ecological way. A part of the solution proposed was the idea to expand the amount of RE in the region. In SHA such a concrete object was missing. There pioneers established the initiative “Energieinitiative Kirchberg” to promote the development of RE in the region as a general contribution towards the change of the energy system.

All the political pioneers had in common that they argued against the conventional forms of energy production, especially the use of nuclear energy, and formulated ideas about a desirable ideal future energy system that were based on ecological motives like sustainability. Their appearance may be characteristic of any social movement in that they created the “vision of a possible better situation and some project of escape from here to there” [44] and established a common frame to legitimize their goals and actions [45]. Their activities were concentrated on formulating a main policy idea and identifying possible allies to help promote it. The latter was crucial as these individuals or isolated groups within society were usually ordinary citizens not connected to political or economic establishments in the regions and were even characterized as “eco weirdos” and, thus, were lacking the necessary prestige to initiate an implementation of their ideas by themselves.

Both the political and technical pioneers saw the utilization of renewable energies as a solution for the problem at hand and were mainly driven by non-material motives. Ecological motives were dominant in the group of political pioneers and amongst many of the farmers as technical pioneers. As a result of pioneering activities, different artifacts were produced. While the technical pioneers established technological artifacts like a biogas plant or wind mill, the political pioneers created documents in which the idea of the future role of RE within the region were formulated. The Agenda 21 group in Lü-Da for example, drafted a resolution and initiatives in Morbach and SHA developed first documents, like flyers, that could be used to present the idea to possible allies.

During this phase, both types of pioneers acted mostly independently from one another. However, among themselves they formed isolated networks connected to a specific issue within the topic of renewable energies, like the political pioneers within the citizens’ initiative in SHA and Morbach and the Agenda 21 group in Lü-Da, or the technical pioneers within the biogas community in Weckelweiler in SHA. These first pre-networks were embedded in specific milieus like the pro-organic-farming and anti-nuclear movements, both milieus in which it was common to think differently as compared to the mainstream discourse occurring in the institutional context.

But in relation to the total population in the region, the pioneers operated in small isolated niches characterized by a different perception of what the “right” energy system should look like, regardless of if it was technical, that is, linked to a concrete technical project or political that is there again linked to a political vision. Because of their isolated position within the regions the pioneers actively sought

contact to actors located outside of their regions. They did this by visiting people or projects with experience in renewable energy.

During the pioneer phase, the process of change had a bottom-up character because the process was initiated by the activities of the pioneers. The technical pioneers were working on a material basis for the process yet to come, or, said differently, the technical know-how and artifacts. On the other hand, the political pioneers contributed the non-material basis, *i.e.*, the idea of self-sufficiency as an argument in the following political debates. Both were isolated starting points for the process, which later joined together to form the origin of a possible transformation of the local energy system.

4.2. The Pivotal Network Phase

In this phase, the pioneers could be adequately characterized as entrepreneurs because they tried to impose their ideas (technical and political) on other social groups. We use a very broad understanding of the term “entrepreneur”, going beyond its mere economical meaning. An entrepreneur is an actor who alleviates a perceived problem and pushes for socio-technical change by increasing the acceptance of the proposed solution. In our case, the entrepreneurs presented an idea to other actors in understandable ways [46] by translating the idea into objects and actions and giving other actors the opportunity to align their interests with the project. The invention gained acceptance and was able to become an innovation.

The political pioneers tried to diffuse their idea of the development of RE within the region. In SHA the citizens’ initiative promoted their idea by drawing on other regions that were present as already successful examples for the realization of the goal of RESS. They organized events with leaders from those regions which could present and share their experiences. In the context of such a presentation the leaders not only highlighted the ecological arguments related to RE, but also point out the economic value added through RE to a region. Also in Morbach, the initiative pushed the issue of a RE-Region on the local agenda through organizing events with pioneers from outside the region. After winning a seat in the regional parliament the initiative had the possibility to regularly present motions related to RE. In Lü-Da, the efforts of the political pioneers went even further by having their resolution, achieving RESS, adopted by the regional parliament.

In this phase, the realization of the potential of the political idea by political incumbents was crucial for the further diffusion of the idea. Political incumbents are people who occupy “exceptional positions” within the existing local political structure. Through their position, they are endowed with particular prerogatives and have the funds to support the idea [44]. In SHA, the political incumbent was the head of the regional business development co-operation; in Lü-Da, staff members of the administration and the newly elected head of the district authority; and in Morbach the newly elected mayor together with members of the administration. In order for the political incumbents to commit to the idea of a RE-Region such arguments as regional added value through the development of RE in the region were determining. The issue of RE was interpreted as an opportunity to promote the economic development of the region. Together with the pioneers, political incumbents started concrete projects with the goal to extend RE and attract external resources to the region. Through their positions, they were capable of linking the new idea with the credibility of their function and could moderate between the pioneers and the rest of the inhabitants in the region that still needed to be convinced. In Lü-Da, the political pioneers

together with staff administration utilized the idea of a RE-Region to develop concepts for application within different promotion programs like ALTENER or “Regionen Aktiv”, both programs had the goal to support regions in their economic development. Within the concepts the idea of a RE-Region were presented as an ideal way to develop the region of Lü-Da. After gaining grants from those promotional programs, concrete RE-projects were realized within the region and the position of a regional manager was eventually installed. During this time different excursion to other regions were organized in order to learn more about RE in a regional context, e.g., the actors involved in “Regionen Aktiv” visiting Güssing, Austria and traveling to Sweden. In Morbach, the mayor and the administration had the idea to utilize the former military area to attract RE-facilities, that is to develop an “Energiewirtschaft” The development of the concept was supported by political pioneers who organized open councils together with the mayor in order to persuade the local population of the project and by a research institution that also demonstrated the link between RE and the generation of added value for the region. Furthermore, the citizens’ initiative, organized for the members of the regional parliament an excursion to Beckerich in Luxembourg, which is well known as a successful example of RE implementation on a local level. Finally, the parliament adopted the concept and the “Energiewirtschaft” was born when the first wind mills and solar panels. In SHA, the regional business development co-operation together with some of the political pioneers had the idea to establish a center for energy that would pursue the goal to promote RE within the region. After the financing was ensured the center was built.

In all cases, one of the dominating goals of the concepts was to facilitate the installation of RE facilities, so that investments and income could be generated within the region. Related to the new political projects, the political incumbents experienced an enhanced status and position, as the topic of renewable energies is linked with regional development and was received positively in the local political discourse. Additionally, the drawing on other regions as successful examples through the organizing of excursion or conferences with leaders played an important role. These activities were coined by an endeavor to demonstrate that RESS was possible. The successful examples were located outside of the region, but were “translated” into the local context and served as positive reinforcements of the idea. By drawing on successful examples, the idea gained legitimacy amongst the population and was actively diffused in the local region as the political entrepreneurs identified relevant actors and approached them actively with their ideas.

With the implementation of concrete political projects, the importance of the political pioneers as entrepreneurs diminished and the role of the entrepreneur passed gradually over to the political incumbents. Therefore, it is not surprising that the following initiative to develop a resolution linked to the goal of RESS was chiefly taken by the political incumbents. In Morbach, the mayor, together with his administration and with the support of a research institution, designed the text for a resolution. In the case of Lü-Da, the new initiative was taken by a member of the administration with the goal to reinforce the first resolution related to RESS. In SHA the case was slightly of different form because the citizens’ initiative was one of the driving forces behind the development of the resolution. Together with the head of the regional business development co-operation and other political incumbents, the resolution was conceptualized.

The technical pioneers acted, at a first glance, like typical entrepreneurs as defined by Schumpeter in that they tried to introduce a new technology into the market [47], but with one important exception: the existing technologies did not get replaced by the new ones, but rather existed parallel to one

another; no “creative destruction” occurred. The technical entrepreneurs went through a learning process by using and improving their knowledge with regard to the favored renewable energy technology, mainly in the bio-energy sector. The technical actors also made contact with successful people or projects related to their technology of interest that were located outside of the region. The entrepreneurs set up a company with the specific goal of marketing their idea. The acceptance of their technical idea by other actors, represented by their buying of the technology, allowed the company to grow and prosper. Involvement and engagement in the company became profitable for the first entrepreneurs. This development was facilitated through a change in the institutional wider-context, the introduction of the Renewable Energy Act (REA) by the newly elected national government of Germany. The REA guaranteed a fixed price for renewable energy above the market price for other forms of energy. This provided financial security for investments in renewable energies.

In SHA, the companies Novatech and S+K were founded by pioneers and in Lü-Da the company Dreyer & Bosse. As already mentioned, in Morbach no home-grown company acted as an entrepreneur, but the company Juwi, which invested in the “Energiewirtschaft” was founded by the aforementioned pioneers which built the first windmills in the region around Morbach. Therefore, in the case of Morbach, the technical entrepreneurs were part of the geographical wider-context.

Parallel to those activities of the technical pioneers, the first followers entered the market, especially farmers from the agricultural sector. In all cases farmers installed their own biogas plant on their farm and started to produce bioenergy. Moreover, in Lü-Da about 60 farmers built a biogas plant with 3 MW (megawatt) together to produce bioenergy based on waste. Also new RE projects developed, in SHA and Lü-Da the first local heating grids were built and in both regions the machinery syndicate organized the ordering of solar panels so the farmers could benefit from economies of scale. In SHA, distinguishable from the two other case studies, regional incumbent economical actors from the energy sector like the “Stadtwerke” (municipal utility) invested in RE and brought forward their own RE-projects in the region. In Lü-Da, some of the farmers became so successful in the area of bioenergy that they were able to concentrate their businesses on producing energy. In these cases, the technical entrepreneurs were not only previous pioneers, but also some of the first followers.

All in all, the technical actors became more professional and economic motives more important than ecological motives. For the farmer, bioenergy was perceived as an opportunity to generate profit in the region based on their production of biomass, in particular because during this time the price for corn remained low. Through their successful engagement in the market place, the entrepreneurs demonstrated that the implementation of renewable energy projects can be economically profitable. This greatly helped the idea of renewable energy gain support within the region and legitimized it among the people both within and outside of the region.

Within the demonstrated activities, the crucial point for the further development of was process of change was that the technical and political entrepreneurs met on common ground and formed pivotal networks around the issue of renewable energy.. In SHA, the different actors came together through the conferences organized by the citizens’ initiative, discussed the issue, gained input from other regions, cooperated to establish a center for energy, and brought forward an RESS-resolution. In Morbach, the emerged network was closely related to the project to establish the “Energiewirtschaft”. In the process the mayor and the administration together with the citizens’ initiative convinced the regional parliament, the local population and the company Juwi, to support the project. After the acceptance of the

concept, the company was organizing the technical realization of the project, while the political entrepreneurs were moderating the process towards the different political bodies. In Lü-Da, the pivotal network was especially centered around the promotion program “Regionen Aktiv”. Together they refined the idea of a RE-Region and managed the realization of the “Regionen Aktiv” program. While the focus of the political entrepreneurs was the diffusion and translation of the idea of the RE-regions to the different political bodies within the region, the focus of the technical entrepreneurs, especially the farmers, was to realize the concrete projects within the program, e.g., the first biogas station in Germany. The participants of the networks assumed different functions and roles. While the political entrepreneur organized contact with political institutions within the regions and drew up documents and other artifacts for the diffusion and translation of the idea, the technical pioneers first dealt with the construction and installation of concrete technical artifacts for the production of renewable energies. However, within the networks, the different roles of the actors were blurred, especially because some of the technical pioneers were engaged in the political discussion on a local level and also managed the contacts to the regional political bodies. All in all, the first pivotal network could be described as a case of heterogeneous engineering [48]. Together the member of the pivotal network shaped new technologies and constituted new coalitions within the political scene in the regions. In particular, the idea of a renewable energy region as an instrument for regional development served as an argument to link the new technologies to the different motives of the involved actors. The pivotal networks pooled the formerly isolated activities, the knowledge, and the enthusiasm for the idea, coordinated them, and represented the idea within the region. Through the adoption of incumbent actors within the region, the process lost its character of being a bottom-up process and assumed a top-down nature. The incumbent actors, supported by their exceptional positions, gained influence and were able to define the agenda.

4.3. The Extended Network and Growing Market Phase

The relationships within the pivotal networks strengthened and new actors entered the field, attracted by the issue of renewable energy and the chance of economic success. The technical and political entrepreneurs, incumbents, and pioneers who began the process remained in regular contact with each other. They still formed the pivotal network for the issue of renewable energy within the region. Together the pivotal network advanced new RE projects, with the main focus to push forward the idea of a RE-Region as a political project that enabled economic opportunities within the region. A milestone regarding these efforts was in all cases the adoption of the idea of a renewable energy region in the respective regional parliaments so that the idea could serve as a guiding vision for the desired transformation. The topic of renewable energy became part of the regional development strategy.

All in all, the idea became institutionalized and was widely adopted by incumbent actors. The idea of a renewable energy region reached political consensus within the local discourse of the political actors. New political projects were advanced as a contribution to the regional development strategy, especially by linking the issue of RE with other topics like tourism or/ and education. In this sense in Lü-Da, a renewable energy academy was instituted; in Morbach, excursions to the “Energieweg” were offered; in SHA, an energy trail was established and a working group with the most important actors in the energy field was established. The regions have gained leadership roles as recognized renewable energy regions; documented by the different prizes they have received for their commitment

to the transformation of the energy system (like in the case of Morbach) or through visits from other regions. The political actors represented the idea beyond the boundaries of their region and it became part of the regional identity. Some of the former political pioneers remain active in the issue of RE in their regions, but most of them have left the networks because, like in the case of Lü-Da, to their displeasure the ecological aspects did not play a prominent role anymore within the process due to the dominating role of the incumbents. In SHA and in Morbach, the pioneers withdrew because their political idea of a renewable energy region had been institutionalized and institutional actors had taken the lead. In some cases, however, it was because the pioneers started a RE business, that is they became technical entrepreneurs.

Aside from political projects, the pivotal networks tried to push forward new technical projects in order to demonstrate their leadership positions. In Morbach, a local heating grid was initiated by the mayor and administration, while in Lü-Da, new RE-projects were started within a new granted promotion program “Bioenergy Region” and the concept of a second biogas station was additionally developed. And in SHA the “Stadtwerke” put in operation, with the cooperation of a technical entrepreneur and farmer, a micro gas grid that is supplied by biogas plants.

In general, however, the majority of the new technical projects were performed by new actors from inside and outside the region that entered the field as independent market actors, establishing discrete business relationships. These actors were either not connected to the pivotal network or were very loosely connected through business relationships. The new market actors did not primarily identify themselves with the political idea of a renewable energy region, but were rather motivated by the opportunity to generate economical benefits. Such an opportunity was, for example, implementing renewable energy projects, like the installation of solar panels or biogas plants. In SHA, two big enterprises from the engineering sector set up production facilities in the region and supra-regional enterprises from the energy sector started innovative energy projects like a production facility for biomethane. Such large enterprises were missing in Lü-Da, but external investors were investing in exclusive bioenergy projects. In Morbach, new RE-firms set up their businesses in the area of the “Energiewirtschaft” and Juwi expanded its engagement within the “Energiewirtschaft”. The economical benefits were facilitated by the increasing profitability of renewable energy projects through changes in the Renewable Energy Act Especially the introduction of a bonus for the utilization of animal waste for the production of bioenergy gave an incentive to farmers to install biogas plants on their farms. Also, the change in the institutional wider-context that entailed the massive rise in the price of oil during this time increased the willingness, in a broad part of the population, to invest in RE. Due to the increased demand for renewable energy technologies when new actors entered into the market, companies of the technical entrepreneurs benefited and were able to grow. As a result of economic success and the market taking off, the companies expanded their business activities beyond the region. The companies became supra-regional actors and competed, in some cases, with their products in global markets.

Thanks to the economic success, some of the technical entrepreneurs left the pivotal network in order to concentrate on their firms.

Therefore, also regarding the diminishing role of the former political pioneer, it can be stated, that the pivotal network showed some first signs of dissolution. The leading role within the network was now mainly held by former incumbents that carried over the role of the entrepreneur into the process. Together with the rest of the pioneers, they formed the new core of the network. The new core became

almost stable with regard to the involved network members. Dense relationships were established and it became more difficult for newcomers to enter the network. Their activities and reputation were closely related to the artifact of the adopted resolution and the technical artifacts that were already well known as success examples beyond the region. The main motive of their activities was regional economic development through RE. The process of change cannot be characterized as a bottom-up or top-down process anymore; instead, the regional process is now influenced by national market dynamics which are again influenced by changes in the national political framework. Within the region, political and economic actors exist who can react to the market dynamics and drive the future process.

4.4. To Sum up: Main Characteristics of the Conceptual Three-Phases-Model

Based on the comparison of the three cases a model was derived summarizing, in an abstract way, the regional process of change. The model presented describes an ideal type, meaning that some parts of the cases are more emphasized than others. The object of the creation of such an ideal type was to generate a heuristic model that could be used as a tool for further research (see Figure 2, Table 2).

Figure 2. The three phases and the process of socio-technical change.

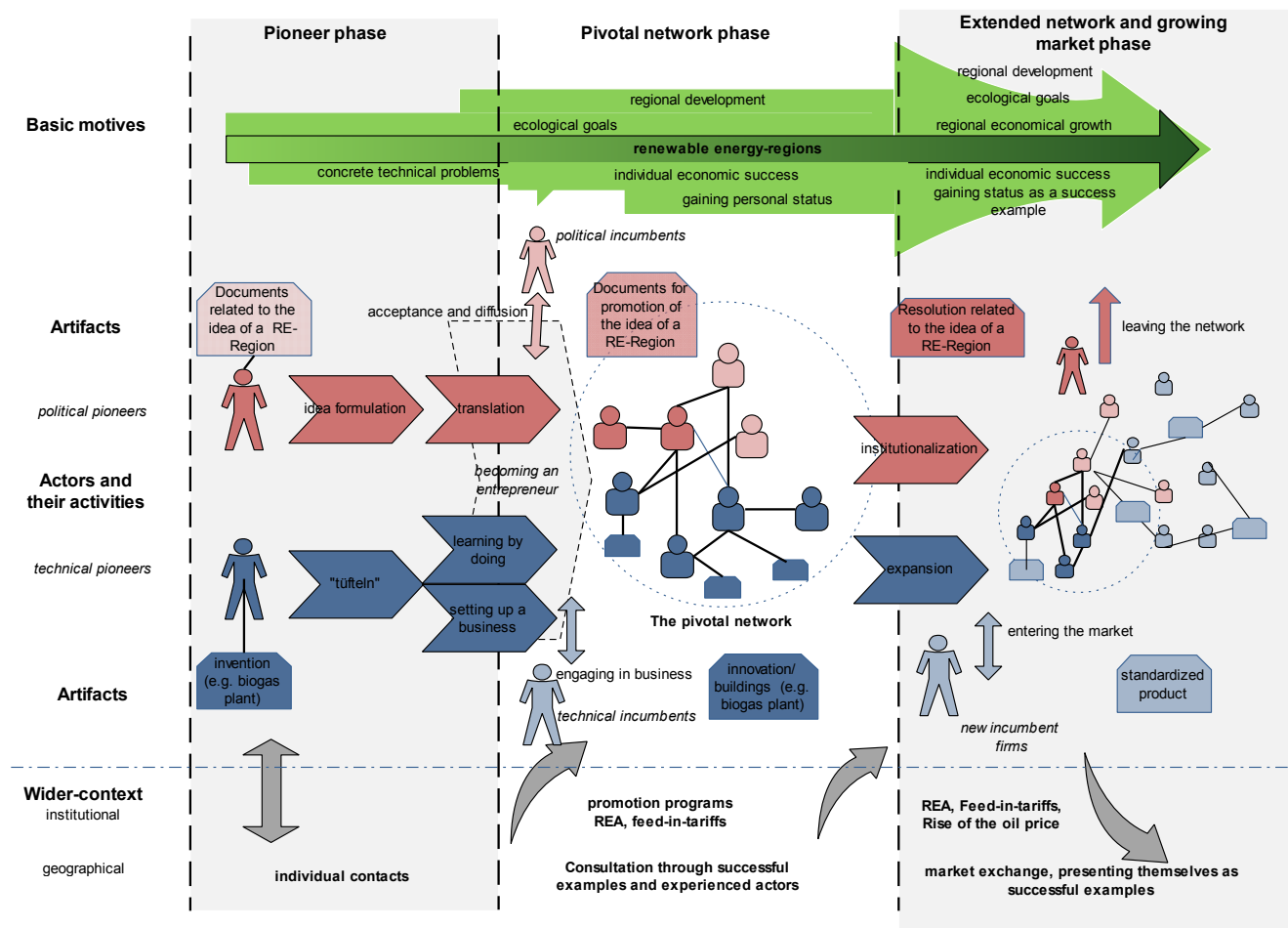


Table 2. The phases and the different combining elements.

Phase	Pioneer phase	Pivotal network phase	Extended network and growing market phase
Wider-context			
Institutional		REA: Feed-in-tariffs Promotion programs	Feed-in-tariffs Rise of the oil price
Geographical	Use of individual contacts to get information	Consultation through successful examples and experienced actors, market exchanges	Presenting themselves as successful examples, market exchanges
Elements			
1. Actors and their activities	Technical pioneers “tüftlen”, finding a solution to a concrete technical problem	Former technical pioneers become technical entrepreneur setting up a business learning by doing Former technical incumbents become entrepreneurs engaging in a new business segment	Companies of the technical entrepreneurs Growing and expanding Gaining market shares Concentrating on their business New incumbent firms are entering the market
	Political pioneers idea formulation for a perceived political problem (RE-Region)	Former political pioneers become entrepreneurs translation, bridging of different motives Political incumbents become entrepreneurs acceptance and diffusion	Political entrepreneurs pushing the idea of a RE-Region or withdrawing from the process The engagement of further political incumbents contribute to the institutionalization
Relation and Interaction	Isolated Single pre-networks between political pioneers or technical pioneers	Network between political and technical entrepreneur forming the pivotal network	Pivotal network is stabilized, former pioneers are leaving it New firms are entering the field of RE without building relations to the pivotal network, market relation becomes more important

Table 2. Cont.

Phase	Pioneer phase	Pivotal network phase	Extended network and growing market phase
2. Basic Motives	Ecological—imagining an alternative state of the world	Regional development Individual economic success	Regional development Regional economic growth
	Pragmatic—imagining an alternative state of a concrete situation	Gaining personal status Ecological and pragmatic goals	Individual economic success Gaining status as a successful example Ecological goals
3. Artifacts	Invention according to biogas plant technology, first RE technologies are installed	Innovative products and new buildings related to biogas plant technology or other RE	Standardized biogas plant technology, installed RE plants New innovative projects
	Formulation of documents according to the idea of a RE-Region	Documents for promoting the idea of a RE-region	Legal text related to the target of a RE-Region
Process Character	Bottom-up	Top-down	Bottom-up and top-down

The *pioneer phase* is characterized by pioneers acting in isolation or in little pre-networks. Their main motives were pragmatic; they were imagining an alternative state of a concrete situation. The technical pioneers were trying to find concrete technical solutions or concrete alternatives to issues like the energy supply to their homes. The results of their efforts were inventions such as those relating to biogas plant technology or other RE technologies. The political pioneers were formulating the idea of a RE-region as a solution for a perceived political problem in their region. They produced first documents in which the idea for a RE-region was presented. Their main motive was to imagine a more ecological, more sustainable state of the world. Both types of pioneers had contact to other pioneers outside the region who provided them with information and support.

After being active as isolated actors in the *pivotal network phase* the pioneers and their ideas became accepted and they connected themselves to other actors under the vision of a RE-region. The pioneers become entrepreneurs. The technical pioneers became entrepreneurs their inventions. Through trial and error products like biogas plants were designed and marketed and businesses were set up. They transformed their single RE-projects into opportunities for economic success. The political pioneers became entrepreneurs by translating the ecological issue of RE to other political actors. This was achieved by representing it as an opportunity for economic development. The pivotal network was formed by former pioneers and incumbent actors who joined the network after realizing the potential of a RE-region and as an opportunity for economic development and possibly, to gain personal status. While for the technical incumbent the individual economic success was important, for the political incumbents the issue of RE was seen as concept for the economic development of the region. The incumbents became entrepreneurs by engaging themselves in the new RE market and by supporting the diffusion of the idea actively. Related to the activities of the pivotal network and beside the diffusion of the idea of a RE-region, is the realization of a concrete RE-project in the region.

During this time documents for the promotion of the RE-region were produced, innovative products marketed and different RE plants were installed. Through the Renewable Energy Act or promotion programs resources were gained in order to promote the expansion of RE in the region. Successful examples outside the region were visited and experienced actors were invited in order to gain advice on how to manage such a process.

In the following *extended network and growing market phase* the pivotal network is stable at this point. The companies of the technical entrepreneurs grew and gained market shares and the political entrepreneurs pushed the idea of a RE-region. The idea of a RE-region was adopted by the regional parliament, which demonstrated the acceptance of the idea of a RE-region. The idea became part of the institutional context of the region so that a new generation of political incumbents supported it as part of their job. Some of the former pioneers left the network because they wanted to concentrate on their own businesses or because they rejected the pure economic interpretation of a RE-region. New firms from incumbents that were not related to the network entered the market because the production of RE was becoming more profitable and also because of the opportunities associated with the REA and rising demand due to the increased oil prices. The main motive was regional development through the expansion of RE, which promised regional economic growth and individual economic success. Ecological motives were interpreted as in line with economic motives. More and more technological artifacts like RE plants were installed in the region, standardized products sold, and new innovative projects started by the actors. A legal text related to the target of a RE-region was instituted as part of the legal framework of the region. Finally, the regions became well known as successful examples of the process of change of the energy system. People from outside the region began visiting in order to learn more about such a process of change.

5. Discussion

The purpose of this article has been to explore the emergence of regional processes of socio-technical change related to the adoption of the goal of renewable energy self-sufficiency. We developed a phase model based on the association of three elements that emerged during the process of data analysis: First, the actors and their activities, second, the motives of the actors, and third artifacts. The three elements of our model have been nested in a geographical and an institutional wider-context. The association of the different elements and the wider-context, and the activities which link them together, constitute the process of socio-technical change. The model itself should not be understood as a theory, but as a heuristic that helps to structure and analyze the phenomena of socio-technical change related to RESS, especially the dynamic relationships between the constituting elements.

Although a similar process of change could be analyzed in every of the three regions, it is important to mention that the process related to the vision of a renewable energy region is—throughout all phases including the last—extended network phase—not actively supported by all citizens within the region. A representative survey in the regions shows that only about sixty percent of the citizens are aware of the goal, but more than eighty percent would support the goal [49]. There are, however, also initiatives against specific renewable energy projects in the regions, and, hence, the process has so far not been a smooth one. The key actors had to face many obstacles and conflicts over land-use, especially related to biomass, wind turbines, and open space photovoltaics, remain. Furthermore, although general patterns

of change have been identified, every investigated region has its own specific circumstances and unique story towards RESS. For instance, different motives have been more important for one region than the other (e.g., the temporary storage site for radioactive waste in the municipality Gorleben and the related concrete anti-nuclear-energy attitude amongst citizens were extremely important for initiating the RESS process in Lüchow-Dannenberg, see also specific institutional wider-context in the appendix, Table I).

This highlights that our cases are associated with a specific historical setting or special conditions. Thus, our model cannot be assumed to be directly transferable to other regions, also because the regions that are striving for RESS have a rural character. Hence, rurality may hold as a general factor and pose a significant limitation in transferring the findings of our paper to urban areas. Therefore, in order to further improve the model, it should be applied in urban cases where a transformation to RESS is occurring.

In all three cases investigated, similar elements were found and ensued in similar “phases”. Furthermore, the identification of the different elements highlights the importance not only of the single elements, but of the association between them; it is not the single element that constitutes the process, but the interaction between the elements performed in activities within a wider context. For instance, entrepreneurs and politicians (actors) are participating in an excursion (activity) to a new biogas plant (artifact) and talk (activity) about added value (motive) within the contextual fact that the energy act is offering a new bonus for using liquid manure (wider context). Taking this into account, it becomes obviously that especially the activities that are forging the links between the different elements are decisive for the constitution of the process of change.

Our examination of the regional processes illustrates that especially the forged links, between the imaginary world represented by the motives of actors and the material world represented by the artifacts, are one of the driving forces of the process. While other approaches regarding socio-technical change have a strong emphasis on “technology...traditional artefacts” [50], our model places emphasis on a co-evolution of the socio-discursive and material-technical side. Crucial for the co-evolutionary character of the process was the alignment of the different motives under the umbrella of the argument of a renewable energy region which acted as a *boundary object* [51] or a guiding vision ([12,52]). A boundary object helps actors from different social worlds to cooperate and communicate while maintaining their autonomy. In our case, this means that the people agreed on renewable energies although they had different motives for supporting it. The issue of renewable energy helps the political pioneers to connect the motives of different social worlds, like the motives of achieving ecological improvement, regional development, and individual prosperity. It also enables the incumbents to identify themselves with the idea or vision of a renewable energy region. The association of different elements of the same type did not occur in a vacuum, but was related to material elements like artifacts. First, the boundary object of a renewable energy region was connected to a concrete problem in the region (e.g., the temporary storage site for radioactive waste in the municipality Gorleben in Lüchow-Dannenberg; in Morbach a former military area). Second, the boundary object itself gets materialized through the adoption as a decision related to the target of a renewable energy region in the regional parliament. And at last, it was related to concrete solutions to reach the goal of a renewable energy region, like the projects started by the technical pioneers. The idea was intimately bound to the material and the technical aspects that make them durable, cohesive, and visible for the people [53]. However, most of the new technological artifacts, such as the inventions from the technical pioneers, were developed

without having a big plan or a vision of an alternative state of the world. These actors were more interested in addressing a concrete problem within their personal environments. Their activities in the field of renewable energies were only later linked to the vision of a renewable energy region. The idea was not only translated into artifacts, but artifacts were translated into an idea, which mirrored the concept of change as “an ongoing process of materialization of ideas, of turning ideas into objects and actions and again into other ideas” [54]. The role of the technical pioneers is thus a good example of the interaction between the socio-discursive and material-technical world. Consequently, the regional discourse on a renewable energy region is not an abstract conversation or one constructed in a cognitive cultural world, but is instead an active interaction with the concrete material world, especially regarding the creation of beacon projects representing the realistic implementation of the vision (e.g., the first biogas station in Lüchow-Dannenberg) and the adoption of the idea as a decision in the regional parliament that is documented in a legal text. Aside from the network of actors which is, as we have shown, important for the process, the existence of a network that link actors and artifacts is crucial for the process, as well. This network is connected by a vision, like that of a renewable energy region, which aligns the different motives held by the actors.

The emergence and associations between the socio-discursive and material-technical world need time and a protected space where it can prosper. In these spaces or milieus, which are already widely discussed under the term of “niches” within the MLP, radical innovation can emerge because they are shielded from mainstream market selection [14]. In our cases, inside of these niches the pioneers, in the MLP often labeled as outsiders, have the opportunity to improvise and to “engage in experiments to work out the best design and find out what users want” [14]. While the MLP put its emphasis on what we called the technical pioneer, our analysis also illustrates the efforts of the political pioneers to put forward the regional discourse. Analogous to the work of the technical pioneers, they formulate in their niches shielded from the mainstream political opinions an idea and engage themselves within experiments to work out the best argument that served to institutionalize the idea of a RE-region. The importance of pioneering activities in establishing an associated network of elements, raises the question of how the elements get associated by actor activities and how do actors develop the capacity to establish a niche and stabilize it? In the explored regions, we found actors who showed the capacity to shape the existing state of the local energy system through their innovative activities or by mindful activities of adaptation to new unfolding situations within the given environment, e.g., new technologies being created, new networks being established, the vision of a renewable energy region being shared and translated, and external opportunities like subsidies or promotional programs being actively used. They were characterized by an innovative personality, a motivation to take personal responsibility for “the bad side of the world” and searching for a better solution (see [55]). As for the political pioneers, the “bad world” was not an abstract construct, but was represented in existing concrete objects located in the region (like the radioactive waste storage facility in Gorleben or the future utilization of a former military area in Morbach). The majority of the technical pioneers did not interpret the “bad world” in such a normative way, but rather aligned the issue to technical and economic problems within their personal settings. For them, “tüfteln”, *i.e.*, the pleasure of pottering around a possible technical solution, was a strong motivation. By favoring an alternative development path they become pioneers after being seen as “weirdoes” for a long time. They were able to imagine an alternative energy system

for their region without non-renewable energy sources and they were able to make this idea acceptable over time.

However, what is the difference between so-called weirdoes that become respected actors in the system and those who remain perceived as such throughout their lives? While the role of actors is broadly discussed and their outstanding role in processes is accepted, there is still vast discussion as to what makes an actor and his activities an accepted personality, a leader a leader, a hero a hero, *etc.* (e.g., [56]). The concentration on single actors helps to explain the emergence of a social-technical change within a region, but cannot explain when pioneers become entrepreneurs, incumbents enter the process, and normal citizens and consumers become part of the change of the energy system. This reminds us not to overemphasize the role of single actors, but to scrutinize the activities of connecting people and the establishment of a collective (e.g., by applying a social movement metaphor, see [44] or by focusing on relationships and processes, see [57]). Here other approaches could be helpful that are not focused only on actors but more on contexts in which actors are nested like institutions, milieus, discourses, or knowledge. Such an extended perspective based on our model could help to understand how the elements are associated with one another through different levels of analysis (e.g., geographical level, levels of governance) and the course of time. Especially in our case, through the combination of different elements a scaling up of the process occurred; first performed by pioneer networks building up and ending in association through the national market.

The take-off of the national market, which was heavily influenced by changes in the institutional wider-context, the national policy of Germany, especially by the introduction of the Renewable Energies Act (REA, German: EEG) represents in our case the moment when the growing mass of citizens and consumers took part in the process through consuming energy based on RE sources. The change to renewable energy reached everyday practices, a part that is mostly ignored in the research about socio-technical change [9]. Through the intervention of the state, the possibility was created to allow the processes within niches to expand and for the new RE technologies to be spread through society [58]. The entrepreneurs became active in national and global markets, while companies from outside explored the region as a sales market. Through the EEG feed-in, tariffs were established, which provided the companies with the resources needed to increase their adaptive capacity in face of the selection pressure found in the overall energy market (see [12]). Other factors and developments in the institutional and geographical wider-context also influenced the process, for example, the change in the energy discourse at the national level, in which arguments like climate change and security of supply, enhanced the argumentative power of renewable energies. The issue of climate change specifically strengthened the ecological arguments for a change in the energy system. Furthermore, political pioneers verbalized the vision and helped to connect the local and regional levels with the discourse taking place on a national and global scale [52]. Through the extension of the markets and the translation between the regional and the national discourse, the regional process immersed itself in the national process of socio-technical change and became a part of it. Regarding the significance of the wider context, the study demonstrates that for future utilization of the model, the conceptualization of the wider-context has to be advanced.

The discussed focus on the association of elements as the driver of the process of socio-technical change has also, in our view, methodological implications. We considered it a specific strength of our approach in that we did not favor one theory that focused on the properties of a process. By taking a

performative view of change, we focused on how the elements were constantly organized by the actions and interpretations of the actors [59]. An economic approach, for instance, would have focused on the technical pioneers and their artifacts, while ignoring the link to the regional discourse. Or the economical interpretation of the term entrepreneur would locate the driving forces of the process within the economical world (especially the market), but ignore the fact that there are different types of entrepreneurs who are also related to other fields of life. Hence, our “interpretative” approach turned out to be very useful for the purpose of providing an explorative, but comprehensive understanding of the socio technical process on the way to RESS.

As for further research, an application of our model for other regional case studies would be a first priority in order to evaluate its usefulness in a broader context. Next to this, theory based analyses of specific highlighted elements and/or their patterns of interaction with each other through space and time could be promising. Further research should, however, not be limited to the description of individual elements of RESS processes, but also strive for comprehensive, system based concepts.

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Conflict of Interest

The authors declare no conflict of interest.

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Appendix

Table I. Summary of the three case histories structured by the different tracks.

Pioneer Phase

Institutional wider-context-track					
e.g., crisis of the agricultural sector in Germany which give an incentive to search for alternatives.					
Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track	Specific regional institutional wider-context-track
SHA (Schwäbisch-Hall)	Single citizens installed the first solar heating systems in the region on their roofs. Construction of a prototype biogas plant managed by a cooperative. First farmers from the organic farming milieu built biogas plants. An especially active biogas community emerged in the small town of Weckelweiler where they pushed projects relating to biogas. Later they founded a bio-energy association.	They installed and built the renewable energy technologies due to ecological motives, even though it was not profitable. The utilization of bioenergy was seen as a part of organic farming.	Different renewable energy technologies in wind and solar energy were installed. New technologies for biomass conversions were developed.	The actors had contact with actors outside of the region that were also engaged in the extension of renewable energy, e.g., actors from another region helped to realize the prototype by organizing the financing e.g., in an agricultural training institute, people from various regions, interested in biogas came together in an informal way.	Organic-farming movement
	The citizens' initiative "Energieinitiative Kirchberg" designed the idea of a local energy system based on renewable energy.	Their motive was based on the assumption that the change of the energy system is essential for the survival of the human race. Also religious and ecological motives were shared.	The idea to expand RE was promoted through documents and an information booth.	e.g., a firm was visited that produced combined heat and power plants supplied with vegetable oil.	

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track	Specific regional institutional wider-context-track
Morbach	A farmer built an oil press to extract oil for his tractor from rapeseeds.	He wanted to find a solution to supply his tractors with energy.	New technologies for biomass conversions were developed.	The actors had contact to other actors outside of the region that were also engaged in the extension of renewable energy. e.g., visited a conference about rapeseed oil in another region	Two students started to develop the first wind project in the region around Morbach. They wanted to try to develop business concepts to link ecological and economic goals.
	The citizens' initiative "Bürgerinitiative Lebendige Demokratie" forged ahead with the idea to increase the amount of renewable energy in the region.	They founded the initiative because they were against the future utilization of a former military area as a leisure park. They wanted an ecological utilization of the area that would bring added value to the region.	The idea of the extension of RE was formulated within flyers.	e.g., the citizens' initiative had contacts to other initiatives or Agenda 21 groups outside of Morbach.	Through the withdrawal of the U.S. military forces, the former military area passed into public ownership. A local discourse emerged about the future utilization of that area.

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track	Specific regional institutional wider-context-track
Lü-Da (Lüchow-Dannenberg)	A single farmer invented an engine supplied with biogas in his garage. Other actors tried to develop the first wind project managed by a cooperative. One actor constructed a combined heat and power plant and an engineer invented the first dry fermentation biogas plant	The farmers wanted to utilize local resources in an economic way. They tried to develop solutions to generate economic income within the region.	Different renewable energy technologies in wind and solar energy were installed. New technologies for biomass conversions were developed and built.	The actors had contact with other actors outside of the region that were also engaged in the extension of renewable energy.	Organic-farming movement
	Citizens invented the vision of renewable self-sufficiency within an Agenda 21 group. Within the Agenda 21 group, actors formed a pre-network. Members of the regional parliament participated within the group. This Agenda 21 group developed an energy resolution linked to the idea of RE self-sufficiency.	They wanted to develop a vision of an energy system based on RE <i>versus</i> the current energy system based on nuclear power. With this vision they wanted to show that such an energy system is possible and thus there is no need for nuclear waste storage facilities, especially located in their region.	In a Renewable Energy working group within the Agenda 21 group, a document was prepared presenting the idea of an RE-Region.	e.g., they were visiting a biogas plant in Mecklenburg-Vorpommern. Contact to a university project that was scrutinizing the ecological possibilities of the region.	The storage facility for nuclear waste from Germany is located In the region, Therefore, the discourse about the future relevance of nuclear power was actively held on the regional level.

Table I. Cont.

Pivotal Network Phase

Institutional wider-context-track				
Decrease of the corn price made it more attractive to invest in bioenergy.				
The Green Party and the Social Democratic Party won the national election. The issue of RE was highlighted.				
Introduction of the Renewable Energy Act which guaranteed prices for produced RE. Through the Act, the production of electricity is automatically marketed and conveyed through the national electricity grid to the consumers.				
Different funding programs to promote regional development were introduced by the national government.				
Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
SHA	Some farmers founded RE-enterprises, especially farmers that were linked to the biogas community of Weckelweiler became very active as entrepreneurs. Companies like Novatech and S + K GmbH are founded. The firms are not only active in the bioenergy sector but also in the installation of other RE.	The motivation was to promote ecological goals in an economic way.	The building of the companies became visible. New RE plants were installed, especially innovative projects	The actors had contact with other actors outside of the region that were also engaged in the extension of renewable energy.
	Many farmers install biogas plants on their farms. The regional machinery syndicate organized the ordering of solar panels for the farmers. Traditional energy enterprises became active within the RE-sector, especially the two "Stadtwerke" (municipal utility) initiated RE-projects in the region.	Actors opened up a new market based on their biomass. They wanted to generate profit and to expand their businesses.		

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
	On a local level, the owners of the companies, the mayor, and other local actors come together to push the extension of RE in their town.			
	The “Energieinitiative Kirchberg” organized events where actors from the region “Fürstentfeldbruck” or the Solarcomplex Bodensee presented a vision of an RE-region.	The lecturer highlighted not only the ecological argument for RE, but also the economic value added through the extension of RE in a region.	The vision was presented through slides that highlighted the arguments.	Actors from regions in which renewable energy is already used were invited to present their experiences.
	The head of the regional business development co-operation (WfG) realized the potential of the extension of RE to generate added value in the region. A local discourse about the goal of RESS emerged.	Extension of RE to promote the regional economy and generate added value in accordance with ecological goals.		The initiative had contact with individual in other initiatives in Germany.
	For the promotion of RE within the region, the WfG established a center for energy in the community of Wolpertshausen	The center should promote the extension of RE in the region.	An institute with the goal to promote RE was established.	
Morbach			Installation of the “Energiewirtschaft” consisting of wind power plants, solar panels and a biogas plant.	Two students founded the RE-enterprise Juwi that is located outside Morbach. Juwi invested in the “Energiewirtschaft”. Their motives were economic success and self-fulfillment.

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
	<p>The citizens' initiative organized events with actors from other initiatives like "Solarverein Trier" where the significance of RE for a region was presented.</p> <p>The initiative pushed the issue of RE in the regional parliament after winning a seat.</p>	<p>Within the events, the ecological argument were highlighted, but also the economic opportunities for a region utilizing RE:</p>	<p>Slides and press articles were published</p>	
	<p>The newly elected mayor realized the potential of the idea of an EE-region.</p>	<p>RE are seen as possibility for regional development by generating added value within the region.</p>	<p>Presentations linked to the idea of the extension of RE in the region.</p>	<p>IFAS (Institute for Applied Material Flow Management), a research institution from outside the region, demonstrated the link between RE and the generation of added value for the region.</p>
	<p>The initiative organized an excursion for the regional parliament to Beckerich, Luxemburg.</p>	<p>The excursions were organized to show that the realization of a RE-region is possible.</p>		
	<p>Together with the administration, the idea to utilize the former military area for the installation of RE was generated. The concept of an "Energielandschaft" was born.</p>	<p>For the mayor the "Energielandschaft" was a solution related to the future use of the former military area. The administration wanted to extend their field of responsibility. For both it was an opportunity to develop the economy of the region.</p>	<p>Documents regarding the concept were produced and discussed within the regional parliament.</p>	<p>Excursions were organized to visit other regions in which the goal of a RE-region was already realized, e.g., Güssing Austria, Steiermark Austria, Beckerich, Luxemburg.</p>

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
	The citizens' initiative supported and presented the concept of an "Energiewirtschaft" to open councils together with the mayor	The utilization of the former military area for the production of RE was, in the sense of the initiative, to produce added value in the region in an ecological way.	Press articles were published and presentations were produced.	
	Different events were held in Morbach; a regional climate summit and a biomass conference to promote the idea of RE. The actors involved in the initiative and the administration were active in the events.			
	A local discourse about the goal of RESS emerged.			The "Energiewirtschaft" in Morbach was awarded with the German Solar Prize.
	The administration together with the mayor developed a resolution linked to the idea of RE self-sufficiency.	Due to the positive feedback related to the "Energiewirtschaft", they wanted to strengthen their image as a pioneering RE region.		The research institute IFAS provided advice for the arrangement of the resolution

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
Lü-Da	One of the farmers set up a business that offered biogas plants to the market. (Dreyer & Bosse)	They wanted to generate profit and to expand their business.	Products were marketed.	
	Farmers installed their own biogas plants on their farms and started to produce bioenergy. Together 60 farmers built a cooperative biogas plant to produce bioenergy based on waste. The regional machinery syndicate organized ordering solar panels for the farmers.	They opened up a new market based on biomass.	Biogas plants were built. A biogas plant with 3 MW was built. Solar panels were installed on the roofs of farm buildings.	
	New projects were developed, like the first local heating grid and the first biogas station in Germany.	The extension of RE was seen as an opportunity for regional development and to create the image of a model region.		
	A resolution with the goal of RESS was adopted by all parties in the regional parliament.		An official document was published that show the different projects and actors related to the goal of RESS.	Funding rewarded within the ALTENER-program and the region is awarded for their vision of a RE-Region as best rural region in Europe.

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
Lü-Da	Linked to the resolution and the vision of a RE-Region, a proposal was made to acquire funding within the European ALTENER program by the administration and members of the Agenda 21 group.		A part of the grants were invested in the making of a feasibility study related to the vision of renewable self-sufficiency. The feasibility study was an important document for other proposals.	
	Members of the administration and other political bodies met with actors of the former Agenda 21 group and farmers and developed a proposal for the promotion program “Regionen Aktiv” based on the vision of an RE-Region. “RegionenAktiv” was formed.	A member of the administration wanted to push the regional development and RE was seen as a way and opportunity to enhance their field of activity. Additionally, Agenda 21 members highlighted the alternative production of energy.	Documents were written to concretize the vision of a RE-Region	Funding within the ALTENER-program. Exchange with other region within the program.
	Due to the growing bioenergy sector within the region, farmers entered the of RegionenAktiv network.	For the farmer it was mainly a new business opportunity.		
	With the funding, different projects in the bioenergy sector were developed, e.g., the first biogas station in Germany.		The position of regional manager was developed in order to promote regional development with the help of RE.	Excursion to Sweden to learn more about installing a biogas station as well as Güssing, Austria.
The administration together with some members of the “RegionenAktiv” group prepared a new re-adoption of the resolution and linked to the idea of RE self-sufficiency.	To win once again the support of the regional parliament for a new funding program “BioenergieRegionen”			

Table I. Cont.

Extended network and growing market phase

Institutional wider-context-track				
Massive rise in oil prices which increased the willingness of a broad part of the population to change to RE.				
Amendment of the Renewable Energy Act and the introduction of a bonus for the use of animal waste as a substrate for the production of bioenergy. This made it even more attractive for farmers to install a biogas plant.				
Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
SHA	The enterprises of the first pioneers grew and extended business to outside the region.	The realization of profit in accordance with their personal ecological goals.	RE plants and facilities were installed.	The homegrown RE companies export and are active on a national level.
	Cooperation between the different economic actors, e.g., a micro gas grid was developed between farmers, the Stadtwerke, and one of the pioneering companies.	New innovative projects seen as investments in a future market.		
	Big economic actors from the energy sector invested in the region, e.g., a biomethane production facility was built.			
	The enterprise Würth Solar built its production facility for photovoltaic in SHA.	They realized the profitable opportunities surrounding RE business.	A production facility for RE was built	The new RE companies export and are active on a national level
	The enterprise Voith developed new kind of engine for wind power stations produced in SHA.			

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
SHA	<p>A resolution with the goal of RESS was adopted by all parties in the regional parliament.</p> <p>A working group was established with the goal to promote the extension of RE within the region.</p> <p>The EnergieZentrum together with the members of the aforementioned working group prepared an “Energieatlas”, which documented what was being done in the region to extend the amount of RE.</p> <p>A energy trail was established to promote renewable energy tourism</p>	<p>RE were seen as an opportunity for regional development.</p> <p>Saw RE as a part of regional development linked to the issue of tourism and the issue of location marketing.</p>	<p>With the resolution, an official document that stated the goal of RESS was developed.</p> <p>The document “Energieatlas” was published that highlighted the different projects and actors related to the goal of RESS was published.</p>	<p>Single RE projects of SHA are well known as successful examples. Therefore the region is visited by different groups from all over the world.</p>

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
Morbach	<p>New RE firms set-up their business in the “Energiewirtschaft”.</p> <p>A resolution with the goal of RESS was adopted by all parties in the regional parliament.</p> <p>Based on what was learned during the excursion to Steiermark, the idea to build a local heating grid based on bioenergy was developed. With the support of actors of Steiermark the planning process for the local heating grid started.</p> <p>The citizens’ initiative dissolved. Members of the initiative left the process, engaged in other political bodies, or started RE business.</p>	<p>They wished to generate profits.</p> <p>They wished to strengthen their leading position as an pioneering RE region and generate added value for the region. Location marketing was used to promote the regional development.</p> <p>With the adoption of the resolution and the establishment of the “Energiewirtschaft” their goals were mostly fulfilled.</p>	<p>With the resolution an official document that stated the goal of RESS was developed.</p> <p>Documents related to the planning process are published.</p>	<p>The “Energiewirtschaft” is well known as a successful example of promoting RE. Therefore Morbach is visited by different groups from all over the world.</p> <p>A second excursion to Steiermark was made in order take a better look at local heating grid.</p> <p>The engineer of the local heating grid in Steiermark was visiting Morbach.</p>

Table I. Cont.

Region	Actors-activities-track	Motive-track	Artifact-track	Geographical wider-context-track
Lü-Da	RE based companies are growing	They wanted to generate profits.		The homegrown RE companies export and are active on a national, and sometimes also international level.
	A lot of farmers started to install biogas plants, investors started to invest in the biogas production within the region. New projects, like a second biogas station, are planned	To generate profit for their business.	Biogas plants were installed.	
	The re-resolution with the goal of RESS was adopted by all parties in the regional parliament.	To attract funding to the region for regional development.		
	Promotion program „BioenergieRegionen” was developed.		Documents related to the program were published	Within the promotion program the region received funding and made contact with other bioenergy regions.
	The former “RegionenAktiv” group was engaged within “BioenergieRegionen” program.			The region is well known as a successful example of promoting RE, especially regarding bioenergy.
	Due to the initiative of members from the former “RegionenAktiv” group, an academy for Renewable Energy was established.	The positive image of the region and the experience regarding RE were marketed as an educational offer.	An educational building linked to RE was installed	The region is well known as a successful example of promoting RE, especially regarding bioenergy. Therefore Lü-Da is visited by different groups that wish to gain further knowledge from all over the world