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Transformation Dynamics in Utility Systems

An Integrated Approach to the Analysis of Transformation Processes Drawing on Transition Theory

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1. Introduction

Network-bound infrastructure systems such as electricity, gas, water and telecommunications currently undergo transformations on multiple levels resulting from various sources of dynamics. These include changes of the regulatory framework - deregulation and liberalization -, changes of the institutional settings and corporate structures, e.g. as part of privatization and internationalization strategies, the introduction of new technologies and the emergence of new practices and cultures of use, for example in the context of mobile phones or the internet. These transformations are of considerable importance for sustainable development because utility systems are closely intertwined with society and nature. The present chapter proposes a conceptual approach for analyzing these ongoing transformations in order to assess the potential for developing sustainable utility services.[1]

Utility systems structure the relations between society and the natural environment. Therefore socio-technical transformations of these systems typically imply transformations of the relation patterns between society and nature, also referred to as social-ecological transformations (ISOE 2000). Utility systems are particularly important, because they enable and structure a large number of activities in firms and private households. Furthermore, utility systems themselves cause important environmental impacts by extracting and transforming natural resources, directing material flows, the production of toxic or radioactive waste, emissions, intervening in local ecosystems etc.

[1] The chapter is developed in the context of the project "Integrated Microsystems of Supply", a participative foresight project that comprises the analysis of dynamics in the electricity, gas, water and telecommunications sectors, the construction of scenarios together with representatives from different stakeholder groups, an evaluation of the sustainability potential of the scenarios and the development of strategy options for and with different stakeholders (www.mikrosysteme.org). The project is funded within the Socio-ecological Research Programme at the German Federal Ministry for Education and Research (www.sozial-oekologische-forschung.org)

Given the high capital intensity and the coupling of technological, institutional and knowledge structures in these sectors, socio-technical transformations tend to be relatively slow and strongly path dependent. There are few windows of opportunity for a departure from the established development paths. Radical changes in market rules, as the ones that have followed liberalization and resulting structural adaptations, open up windows of opportunity for developing more sustainable utility sectors. On the other hand, this situation also exhibits the danger to lock-in new but not more sustainable structures for the decades to come.

In this chapter we propose an analytical framework for the analysis of transformations at the level of individual sectors that also takes interactions between different sectors into account. We will illustrate how this concept can be applied to analyze transformation processes in the utility sector.[2]

Transformation processes result from dynamics at different levels: a) dynamics located at the meso level of sectors, b) dynamics rising up from the micro level of corporate and individual actors as utility companies, political actors and consumers, and specific innovation projects, c) dynamics resulting from processes at the macro level of broader societal, technological or ecological developments. Moreover, how the utilities will look like in the future is dependent on interactions within and across different action fields such as provision of utility services, the consumption of these services and the political governance of both.

In order to analyze the transformations of the utility sectors we start from the approach of "technological transitions", as developed by Rip, Kemp, Schot and others (Kemp 1994; Schot et al. 1994; Rip/Kemp 1998; Schot 1998) on the basis of insights from evolutionary economics and technology studies, and which has recently been elaborated by Geels (2002a;b).[3] However, for our problem at hand, the transition theory approach has to be extended in three ways:

- A stronger emphasis on non-technical sources of dynamics is needed, particularly institutional and service innovations.
- Most of the recent work in transition theory has concentrated on changes of single regimes or on the emergence of new regimes. In order to analyze transformations in the utility sectors emphasis is needed on the interaction between regimes.[4]
- A stronger consideration of transformation processes that follow other patterns than ideal type transitions – a so-called regime shift symbolized by an s-curved dynamic from one stable configuration to another one – is necessary.

In the following we will first give a brief outline of the multi-level framework of transition theory. We will then present major transformation processes currently happening in the utility sectors in general and we will argue for the necessity to consider also other transformation processes. Chapter 4 proposes a concept of socio-technical niches which goes beyond the technological focus. Chapter 5 then sketches a framework for analyzing multi-regime dynamics and presents potential dynamics in the utility systems resulting from these interactions. We will sum up in chapter 6 how transition theory can be fruitfully applied for the analysis of sustainable utility sector transformation.

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2 However, a thorough empirical analysis is beyond the scope of this chapter. For a more encompassing analysis see Konrad et al. (2004).

3 For a critique see Berkhout et al. (2003).

4 An extension of transition theory to the analysis of multiple regimes is the aim of a project recently started at the University of Eindhoven (see http://www.tm.tue.nl/capaciteitsgroep/aw/tech_studies/researchplan_feb2003.pdf).

2. The Multi-Level Framework

In this chapter we will give a very short overview of central building blocks and assumptions of transition theory: the concept of socio-technical regimes, the embeddedness of regimes in a multi-level framework and implications for socio-technical change to occur or to be brought about.[5]

According to Geels (2002b: 14) a *socio-technical regime* is defined as a socio-technical configuration, which fulfills a societal function, consisting of artefacts, user practices, markets and distribution networks, infrastructures, policy, laws, regulation, capital and finance. Socio-technical regimes are organized around the specific societal function, which is fulfilled by the socio-technical regime. The concept of regime refers to the rule-set or grammar which guides, but does not fix, action and cognition, for example by providing search heuristics for problem solving and innovation or roles of behavior (Kemp et al. 1998: 182). This rule-set may also be called a "semi-coherent web of rules", since these rules are coordinated, yet not necessarily perfectly aligned, so that tensions and frictions within the regime may emerge (Geels 2002b: 106).[6] The interrelations of the elements of a technological regime provide on the one hand a stabilizing function for the whole complex. Stabilization does not exclude change, but it gives a direction to change which makes certain changes much more likely than others and incremental changes more likely than radical changes. On the other hand, if changes in parts of the regime occur, due to the interrelations further changes may be induced.

Technological *transitions* are conceptualized as a change from one more or less stable socio-technical configuration to another (Geels 2002b: 15). Against the background of this conception we define *transformations* as major structural changes not necessarily of, but also *in* a socio-technical configuration, that is not necessarily a change *of* the socio-technical configuration as a whole. If these changes will ultimately be part of a larger transition process, is often impossible to predict in advance. Furthermore, they may not follow a dynamic pattern of a smooth s-curve from one stable state to another, but may include other macro dynamics, including steady incremental changes, cyclical movements or catastrophic changes.

The multi-level framework refers to a set of interrelated processes at three levels (see figure 1). Socio-technical regimes at the meso level correspond largely to the level of sectors. In contrast to incremental innovations, which may emerge within established regimes, radical innovations are typically generated in *niches* at the micro level. Niches are defined as socio-technical environments, for instance application domains, which are characterized by specific selection conditions diverging from the dominant regime (Hoogma 2000: 80ff.).[7] Niches are important for socio-technical change, because they provide a space for learning about design specifications, possible

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5 For more detailed presentations of the approach see Kemp (1994), Schot (1998), Rip & Kemp (1998), Kemp et al. (1998), Rip (2000); Geels (2002a; b) and Hoogma et al. (2002).

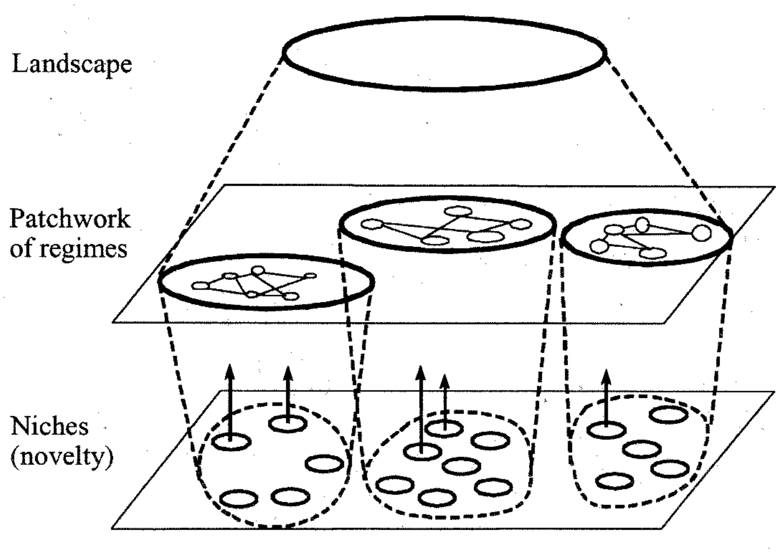
6 Therefore the concept of regimes refers to a less strictly coordinated entity as a narrow conception of a system would imply.

7 Two types of niches are distinguished. The first type refers to so-called *technological niches*, which are explicitly built up to provide a protected space for innovations to be tested and to gain experience. A typical example would be experiments and pilot projects with new technologies, which do not have to be economically viable, which might still show technical problems, or which do not have to fully comply with the usual regulatory requirements. In evolutionary terms this is to say that selection criteria are suspended or weakened or that the innovation is only partly exposed to the selection criteria (Hoogma 2000: 81f.). *Market niches* are also characterized by locally specific selection criteria. However, these are not the result of specific protection measures, but rather due to specific characteristics of an application domain and certain user groups, or they have been developed on the basis of a former technological niche (Kemp 1994; van den Ende/Kemp 1999; Geels 2002b: 100, 114).

ways of using and user requirements, new meanings, societal and environmental impacts, production and maintenance and the adequate regulatory framework (Hoogma et al. 2002: 28). Furthermore, niches allow for the build-up of supporting actor-networks. Major socio-technical changes as regime shifts typically start from niches and rely on a dynamic of niches: an expansion of niches, which eventually leads to the replacement of the old regime; a technology may also be implemented in a succession of different niches (niche branching or niche-cumulation) or the emergence of a new regime relies on the interaction of multiple niches (Schot 1998; Geels 2002a; 2002b: 121ff., 326f.). In the process of niche branching the technological design as well as the application domains may gradually depart from patterns that at the beginning had been rather similar to the respective regime (Hoogma 2000: 341ff.).

Rather inflexible or slowly changing structures external to a socio-technical regime are defined as part of the socio-technical *landscape* at the macro level. These external structures consist for example of macro economic developments, demographic trends, cultural changes, broad political changes or environmental problems (Geels 2002b: 109). They may have a considerable impact on the transformation dynamics of a regime, yet they cannot easily be influenced by the regime actors.

Figure 1: The Multi-level framework (Geels 2002a: 1261)



Whereas transition theory has situated dynamics largely as rising up from the bottom of niches, forcing itself on the predominantly stable regimes and landscape, Geels (2002b: 104) has rightly criticized this bias towards the novelty following a kind of heroic "David and Goliath storyline". A concept of technological transitions must also consider dynamics at the level of regimes, internal dynamics of certain elements of regimes as user practices, technology, policy, industry structure, or dynamics at the landscape level. Nevertheless, the interplay of these internal dynamics may lead to tensions in the regime, which will open up windows of opportunities for novelties and thereby may also lead to broader changes.

Before we elaborate on how we think the transition theory approach could be fruitfully expanded, the next chapter gives a short overview of relevant transformation processes going on in the utility sectors. As will be shown, changes starting from the landscape level have been just as important as changes at the level of niches – niches based on technological as well as non-technical innovations (see also chapter 4).

3. Transformation Processes in the Utility Sectors

One of the major changes happening at the landscape level which is common to all utility sectors is the recent break with regulatory paradigms associated with the provision of these basic services in industrialized societies. Meanwhile these changes have had an impact on most sectors at the regime level, as regulatory structures or organizational forms have been altered in many countries as a consequence of the new market orders.

In the course of industrialization, the provision of water and gas, sanitation, public transport and electricity were key factors for generating widespread welfare and setting the basis for other industrial activities to prosper. Originally in the late 19th century, these basic services were often provided by private firms.[8] However, due to lack of investment, ruinous price wars, and the fundamental importance for health and welfare these sectors got more and more transferred into state owned property or at least into regulated monopolies with tightly prescribed service levels and the obligation to deliver their service in a non-discriminatory way to all citizens in a given region. This understanding of utilities as a basic and taken for granted element of modern life was unchallenged and expanded over almost a century in most industrialized societies.

During the 1980ies, however, this fundamental consensus began to break up. This transformation at the level of the landscape had strong ideological origins (Gray 1998) or served to reorganize power relationships between utility operators and regulating bodies (Hirsch 1999; Young 2001). Once liberalization, deregulation and privatization got introduced into the political debate many of the taken for granted elements of the former utility regimes seemed to be at disposition. The changes at the level of the landscape were therefore weakening a series of relationships stabilizing the dominant regimes. The specific transformations in the different utility sectors may, however, differ quite strongly. Also within sectors in different national markets, as the example of the EU shows, a wide range of developments is possible. All the sectors are affected by the new ideas and the emerging paradigms about the good way to produce and supply utility services.

Transition theory may here be fruitfully applied. We shall therefore shortly sketch in how far the notions of landscapes, regimes and niches may help to grasp the different transformation processes. We will start from a notion of regimes which is strongly related to the sector definition of conventional utility services, i.e. electricity, gas, drinking water, waste water, telecommunications etc regimes and their transformation. A high degree of similarity exists between these different regimes. They in general deal with a commodity which is produced or generated in specific geographical locations and is distributed across a wide spanning physical transportation infrastructure towards the fixed points of consumption spread more or less evenly in space. Demand is taken as a given external factor to which the provision of services has to adapt. The distribution infrastructure is thus an important asset and normally has considerably long life times (20 to 100 years). As a consequence, turnover times are high and the introduction of new products and production processes is bound to follow strongly entrenched paths. Innovation is therefore rather slow and of a more incremental type.

This technological infrastructure is complemented by rule sets and institutions which are (or rather used to be) of comparable durability. Producer associations and

[8] For Great Britain see Guy et al. (1999).

governmental regulators determined the long term development plans of the construction and expansion of infrastructure (Hirsch 1999). Expansion plans were based on long term projections of past growth characteristics. The evaluation and selection of innovations was managed at the level of working groups in the national sector associations as a problem of negotiated search for a common way to proceed. Economic efficiency was of minor importance as investments were financed on the cost-plus principle. Consumer preferences played a minor role because of the high degree of homogeneity by which these services were characterized. Consumers on the other hand were rarely interested in these services because they often did not directly consume electricity or gas but rather the end-use services like light, heat or entertainment. All these characteristics led to a strong orientation of the actors on technical characteristics, low visibility and strong path dependencies over almost a century.

The recent landscape changes in the regulatory paradigms of these sectors are complemented by not less dramatic changes in fields like basic technologies. The former strong reliance on big plants, based on increasing economies of scale is more and more challenged by new more flexible I&T based alternatives, which increase the attractiveness of customer specific appliances. Therefore, long distance transport becomes less of a necessity and new decentralized topologies of service production and consumption come into reach. Concomitantly with these new technological conditions, new use patterns emerge. This is most obvious in the case of telecommunication, e.g. newly emerged use patterns of the internet or mobile phones. Furthermore, new service concepts are developed in niche markets, e.g. energy services such as the operation of customer appliances or the rental of efficient appliances. Increasingly mobile appliances also create new markets for highly decentralized electricity generation and storage etc. Former generalized concepts such as the separation between producers and consumers (e.g. in the case of electricity) or the separation between heat and electricity provision (e.g. in the case of natural gas) are therefore likely to give way to new constellations, which will increasingly threaten key stabilizing forces of the established sector regimes.

However, an analysis of ongoing transformation processes – as in our case – cannot know from the beginning, if these transformation processes will ultimately lead to a shift of regimes. Transformations may also be restricted to incremental changes or follow a different dynamic pattern. Hence, for a prospective study a broadened perspective is necessary, which considers the dynamics on all three levels independent of the final outcome. Secondly, it is often impossible to decide beforehand whether or not a specific alternative scenario will be more sustainable or not. Therefore, we cannot presuppose that a regime shift is the only way to go for. This calls for an expansion of the analytical focus of transition theory, which so far focused on radical transformations following largely an s-curve-shaped transition, and possible paths and dynamics leading to them. Studies have either analyzed historical regimes shifts (Schot 1998; Geels 2002b), or – as far as current or future transformations are concerned – have chosen a normative perspective, starting from the assumption that a sustainable way of fulfilling certain societal functions, for example transportation, can only be realized by a radical break with existing regimes (Kemp 1994; Kemp et al. 1998).

Transformations do not only happen within the individual utility regimes. One may expect a high degree of similarity between the processes across different sectors. Furthermore, the relationship between these sectors is likely to change too. Recently the concept of internationally operating multi utilities has gained increasing attention. By offering bundles of services, utilities hope to reap considerable synergy in the distribution and create substantial added value on the side of consumers. On the other side, jointly used, constructed and maintained physical infrastructure could be a source of considerable cost savings. The conventional understanding of utility services and its organizational form is therefore potentially subject to change, as well. Whether or not these synergies may be reaped is an empirical question. On the local level, municipal utility companies have practiced the multi-utility approach for decades, yet under different conditions. Given these transformation potentials, similarities and synergies, however, we have to enlarge the conventional focus of regime analysis to the interaction between regimes and add to the potential regime dynamics such processes like regime merging, regime split up or regime cross over.

Summarizing, we may describe transformation processes in utility sectors happening at all three levels of transition theory: landscapes, regimes and niches. These transformations have a potential for radical change. As elaborated above, we see three major aspects in which processes should be analyzed in more detail in order to grasp the future dynamics of utility services: (i) the potential to develop more decentralized structures for provision and distribution of infrastructure services, (ii) a strong transformation in the producer-user interface leading to more service oriented utility products and (iii) the structure of relationships between the utility services. Future transformations of the utility sectors are likely to include one or several of these aspects. The more these transformation dimensions will change, the more radically different will be a future utility system compared to the former one. In order to be able to discuss these transformations however, some additions to the existing body of literature on transition processes, regimes, niches and landscapes are needed.

4. From Technological to Socio-Technical Regimes *and Niches*

In chapter 2 we presented the concept of socio-technical regimes. This concept of socio-technical regimes implies a modification to the concept of technological regimes as it was introduced by Rip, Kemp, Schot and others. Kemp et al. (1998: 182, our italics) defined it as „… the whole complex of scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology. A technological regime is thus the *technology-specific context* of a technology ...". In contrast to the notion of socio-technical regimes it puts a certain technology or technological system at the center, social elements are grouped around this technological core. We prefer the concept of a socio-technical regime since – by putting the societal function to the fore – it implicitly avoids the a priori decision that the societal function fulfilled by a regime is primarily fulfilled by a technical core, which itself is depending on *secondary* non-technical context elements. If a regime is primarily defined by the societal function it fulfills and not by a core technological system, non-technical elements might just as well be as central as or even more central than technological elements. In the case of energy, water and telecommunications as they are provided for in industrialized countries today, large technical systems are indeed central elements of the regimes. Nevertheless, at other times and in other places, regimes of the provision of water, energy or communications had been and still are organized less technology-intensive, yet could still be described as a socio-technical regime.

Starting from this definition of a socio-technical regime we think it necessary to take one step more and extend the broader socio-technical conception also to the micro level.

Just as with *technological* regimes, technological niches comprise a set of heterogeneous elements centered around a technological core of *technological* innovations. However, innovations showing a potential to change a regime in a significant way are not necessarily technological innovations. We therefore propose the concept of socio-technical niches.

Transition theory and literature on strategic niche management has so far concentrated on the role of niches for *technological* innovations and eventually regime shifts (Kemp 1994; Schot 1998; Hoogma 2000: 81; Geels 2002b). An exception to this are Hoogma et al. (2002) and Truffer (2003), who – in the field of private and public transport – analyzed niche dynamics also for organizational innovations and innovations related to patterns of use. These innovations included new use patterns of established technologies or new organizational forms, more precisely institutionalized forms of ownership and use differing from the dominant regime (car sharing, various rental concepts), or the organizational coupling of separate regimes.

We propose to continue in this direction. The core of a niche innovation is not necessarily a new technology, but might just as well be organizational, product, service or institutional innovations, which are not applied on the regime level, but only locally. Considering transformation processes in the utility regimes these are, for example, innovations such as performance-contracting of energy services for hospitals and wellness facilities, new regulatory concepts such as least-cost-planning or green tariffs which have first been introduced by some pioneering municipalities or emission trading schemes first introduced within some big companies. Non-technical innovations are particularly relevant for the above mentioned transformations in the dimension of services.[9]

5. Interaction of Regimes

Transformation processes in the utilities are not restricted to transformations concerning one regime; rather several regimes are involved, interactions between these regimes may contribute to the transformation dynamics and transformations may also lead to a shift of regime boundaries. To analyse these dynamics we first have to consider, where regime boundaries may be identified (5.1). We will then identify different types of relationships between regimes (5.2) and finally present potential coupled dynamics of a multi-regime system (5.3).

5.1 Delimitation of regimes

When using the concept of regime in the field of utilities the question arises at which level this concept should be fruitfully applied. Does it refer to sector-specific regimes as a gas or water regime? Or rather to an overarching utility regime spreading multiple sectors? Or is it more reasonably applied below the level of sectors, e.g. to specific socio-technical configurations which have evolved around certain generation technologies like nuclear or wind power? To answer this question we have to consider, how regime boundaries may be identified. We propose to identify regime boundaries according to the density and strength of couplings between the elements of socio-technical configurations.

We differentiate between different kinds of couplings namely functional and structural ones. As functional couplings we identify input-output relationships between different elements, e.g. parts of the value chain. A further example would be enabling products or services of one sector for another, e.g. the coupling between the gas and electricity sector via a gas turbine driven power plant or the provision of telecommunication services for the regulation of power generation technologies.

9 In parallel to the concept of technological niches, it is useful to distinguish between socio-technical niches, where selection criteria are explicitly and strategically suspended or modified, and niches, where diverging selection criteria are due to given local characteristics (see Note 7). We will call these *protected niches* and *market niches*. The term *socio-technical niches* refers to both.

Structural couplings refer to elements which are at the same time part of two overarching complexes. These may be jointly used material structures, as water reservoirs used for the production of drinking water and power, or jointly used transport infrastructures, e.g. powerline cables used for telecommunication services. Structural couplings may also exist at the institutional level. These may be joint organisations as modern multi-utilities or traditional municipal utilities, joint professional associations of gas and water as they exist in Germany and Switzerland or laws and regulations applied to multiple sectors. On a normative level a further example may be the common conception of a basic service which is provided in an undifferentiated way to all citizens of a certain region, a public service.

If structures merely show a high degree of similarity between different sectors but do not actually constitute a common institution, organisation or material artefact we will not speak of structural couplings but of structural similarities.

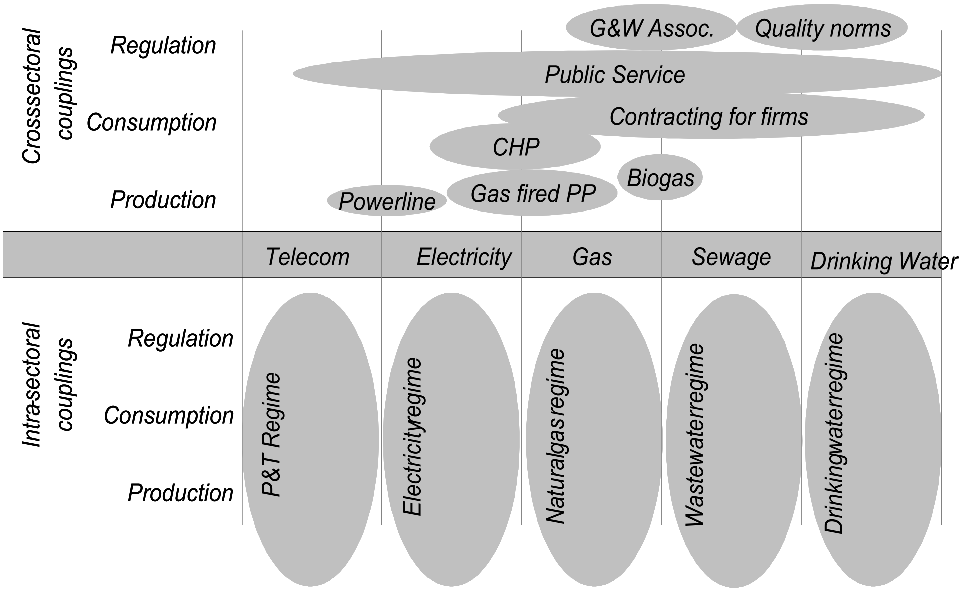
A boundary between two regimes may now be identified if we find relatively dense and hardly substitutable couplings within a complex of elements, whereas couplings between these complexes are less dense and more easily substituted. Furthermore, couplings within a regime will typically spread different structural dimensions as technologies, institutions or knowledge structures. In addition, as outlined in chapter 2, a regime as a whole has to fulfil a certain societal function.

Under monopoly market conditions the sectors considered here can be described as five regimes: an electricity, gas, drinking water, sanitation and telecommunication regime. They are characterised by a high degree of similarity as we expounded already in chapter 3 and a number of couplings exist between them; however these are less dense as the ones within. Within these regimes specific and largely independent institutional and technical structures have emerged. These are specific networks and generation technologies and largely specific organisational structures – either as independent companies or highly separated organisational structures within a utility company. The regimes were largely based on different resources, regulatory bodies and laws; the provision of the services was based on specific knowledge and differentiated professional structures. We split up the water sector in a drinking water and sanitation regime, since these are also largely based on specific networks and appliances, specific organisational units and professional associations, knowledge and professional structures; also the societal perception of these two services differs substantially.

The concept of a regime may to some extent also fruitfully be applied to the socio-technical configurations which have developed around specific generation technologies, e.g. in the electricity sector, if these consist of a densely coupled and mutually stabilising set of technological, institutional, knowledge and value structures. However, these are functionally highly – and *so far* in a hardly substitutable way – coupled to the overarching electricity regime.

Still the delineation of a specific regime may never be made as clear-cut as we may wish. There may be strong structural couplings at certain points of the value chain between regimes and other relationships within a specific regime may be in principle substitutable by alternatives. In the following figure 2 the structure of the different utility regimes is depicted as we may identify them for the times of monopoly market regulation.

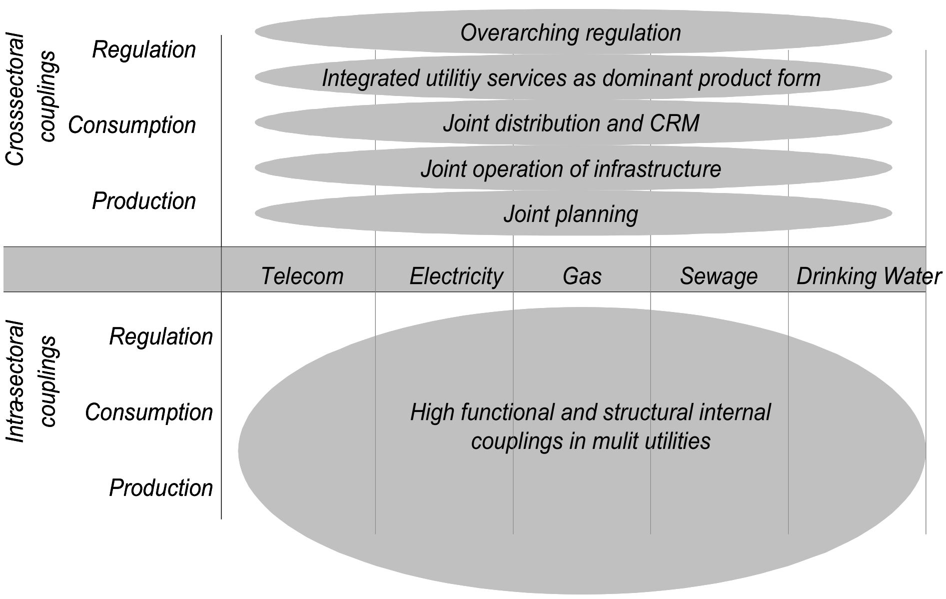
Figure 2: Representation of the inner-regime and cross-regime couplings for the case of monopoly market regulation.



However with ongoing deregulation, utility firms have begun to restructure their business fields and this may have impacts on the interaction of the formerly separated regimes. Some international utilities for instance began to position themselves as multi-utilities combining several services into combined offerings. Transformations may lead to the merging of formerly separated regimes, the splitting into sub-regimes or the integration of regimes at different levels of the value chain as in the case of vertical integration.

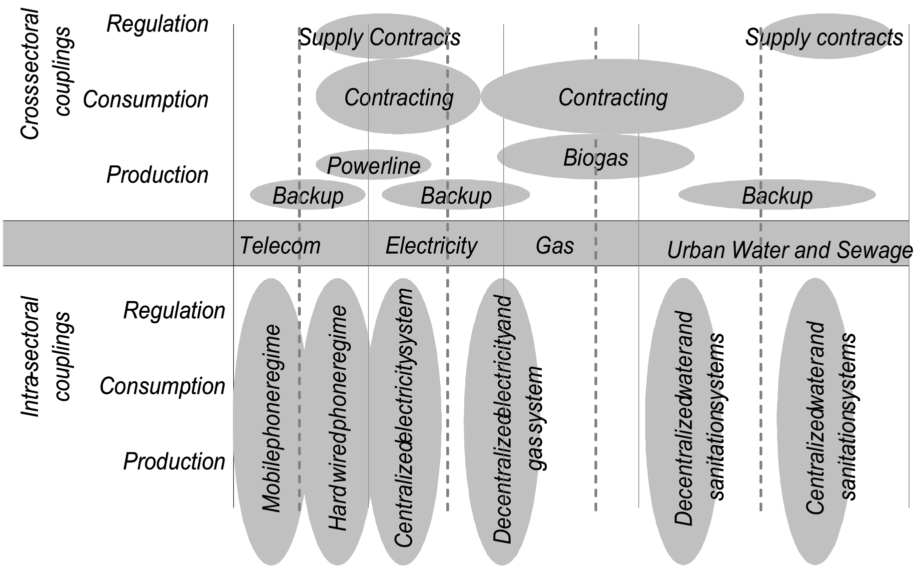
For illustration, we may identify two extreme scenarios which still seem realistic. On the one hand a strong integration of utility services may happen by the way of emerging new multi-utilities, the creation of overarching market regulators spanning all utility services, the joint planning, construction, maintenance and use of transmission infrastructures and the diffusion of new generators such as gas power plants. For the water part a strong integration between water provision and the waste water part seems feasible (figure 3).

Figure 3: Possible future regime of integrated utility services



However, also much more diversified developments may be imagined. The following figure 4 shows a newly reorganized set of utility regimes, which are not based on conventional media differences but which rather follow technological imperatives. There might be a new decentralized electricity generation regime, which is combined with a centralized gas regime. This regime would still have to rely on some services of a centralized electricity regime. However, technologies, use patterns, institutions, knowledge and values might be largely different when the centralized and the decentralized regime are compared. A similar situation might be imagined for the water sector, if used water is recycled within the household or a firm and the dependence on a centralized water provision system amounts only to a fraction of the quantities compared to the current situation.

Figure 4: Possible future regime of reshuffled utility regimes based on a dual centralized/decentralized structure.



Summarizing, we see that in order to discuss the future development alternatives of utility services, the focus of a single regime system is not sufficient. The changing relationship between regimes, the mutual influence between regimes becomes a major driving force and may be decisive also for the sustainability dimension of these sectors. In the following, we will discuss these interactions on a more systematic level.

5.2 Interactions between regimes

For the analysis of interactions between regimes, which exert an influence on transformation processes in the utilities, three types of relations between regimes have to be taken into account. Each type of relation implies different forms of interactions. We will first describe the three types of relations and then exemplify, which transformation dynamics between multiple regimes may result on the basis of these interactions in the case of utility systems.

Interactions between regimes fulfilling a similar societal function: Most studies of the historical development of regimes and regime shifts focused the competitive relationship between regimes, which fulfil a similar societal function. A prominent example is the interaction between private and public transport competing for passenger travel (Kemp 1998; Hoogma et al. 2002). Competition in end user markets can be seen as a specific form of a structural coupling between two regimes.

Interactions between regimes on the basis of complementary relations: Regimes are functionally coupled with other regimes. For example utility systems are coupled with a large number of regimes, which structure the different uses of the utility systems. These receiving systems may themselves be structured as specific socio-technical regimes fulfilling a specific societal function such as laundry, body hygiene, food preparation and preservation, room heating and cooling or telephony in the case of private households or pulp-and-paper-production, aluminium production etc. in the case of industrial activities.[10] The latter types of regimes – in our perspective from the utility sector, we may call them "use regimes" – often develop in co-evolution with the utility regimes.[11]

Interactions between regimes showing structural similarities: interactions between different regimes may also take effect if structural similarities between two regimes exist. Interactions may in these cases take the form of transfer of experiences from one regime to the other or because structural similarities open up synergies, which may be reaped by forming new structural couplings.

The three types of relations are not mutually exclusive. Regimes competing for certain markets may have important structural similarities as in the case of gas and electricity. However, this must not be, as can be seen with the more structurally diverse regimes of public and private transport. Furthermore, regimes fulfilling in some instances a societal function competitively may fulfil this societal function complementarily at others (see below).

5.3 Potential transformation dynamics between utility regimes on the basis of competitive and complementary relations and structural similarities

Interactions between regimes may contribute in two ways to transformations of regimes: as transformation processes *by* interactions between regimes and as transformations *of* the structure of interactions. In the following examples in the field of utilities for both forms of transformations are given.

Transformation by interaction: firstly dynamics in one regime may trigger off or contribute to dynamics in other regimes mediated by direct and indirect linkages between regimes.

Transformation of interaction: secondly the structure of couplings and interactions itself may be modified in the course of transformation processes. The result may be an intensification of the couplings between regimes, which may eventually lead to a shift of regime boundaries and an integration of regimes. On the other hand, a decoupling of regimes or a shift of couplings, which does not imply changes of regime boundaries, is possible. The new structure of couplings will then affect further transformation processes.

5.2.1 Transformations on the basis of structural similarities

Regimes showing structural similarities are not necessarily coupled in any direct way. Nevertheless, transformation by interaction is still possible if transfer of experiences or imitation takes place. This applies to forms of regulation, most obvious in current tendencies towards liberalisation in all utility sectors, but may also apply to changes in organisational structures, for example concepts of privatisation or internal corporate structures, customer management or new service offerings.

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10 For the laundry regime or laundry as a "system of systems" see Shove (2003). The concept of use regimes for the laundry and other domains has also been applied by Hirschl. et al. (2002).

11 For the laundry regime see (Orland 1991; Shove 2003), for the co-evolution of electricity and a number of energy-intensive industries Myllyntaus (1995), for air conditioning Shove et al. (1998).

Structural similarities may furthermore form the basis for actualising potential synergies. In the case of utilities, we currently see such efforts in the form of integration or co-ordination in fields as customer management and network operation. Synergies exist here for instance in the parallel or coupled laying of cables and mains, such as telecommunication cables parallel to gas mains or in sewage canals, or the co-ordination and integration of maintenance activities for different networks. In the field of customer management billing, metering and customer services could be integrated. Synergies are particularly important for structurally similar regimes, since synergies are more likely here than in other constellations. On the other hand, we may also find decoupling of processes, if former structural couplings are found to lack sufficient synergy at a later point of development. Generally these interactions are situated between specific elements of the regimes, e.g. specific parts of the value chain. They do not apply to the regime as a whole. Therefore increasing integration at one point of the linkages between two regimes may well go along with a decreasing integration at another.

The realisation of synergies between two or more regimes will easily bring about structural changes in the respective regimes. These are for example changes in processes, competencies and the organisational structures of companies, which may further go along with changes of corporate culture. Technological innovations may be implemented and patterns of qualification have to be adapted. In Germany new training courses are offered now that prepare for an integrated maintenance of networks (Rothenberger 2003). These structural changes do not *necessarily* imply profound changes in the overall regime structure. However, a dynamic is possible, where a stronger integration of regimes could induce further changes on the basis of the new structure of intensified interactions. A successful cooperation in the operation of networks could pave the way for the introduction of new integrated generation technologies and thereby a much stronger coupling of regimes. In quite the same way successful integration of customer management may be a first step in the direction of new offers of integrated services. An introduction of new integrated generation technologies and integrated services would most probably result in major changes in the utility regimes. Dynamics of this kind illustrate why in a prospective perspective it is difficult to differentiate between dynamics which do 'only' lead to limited transformations of a regime like the cooperation in the operation of networks or the integration of customer management and those, which ultimately result in more profound regime changes.

5.3.2 Transformations on the basis of competitive relations

Transformations by interactions on the basis of competitive relations could follow a shift from the use of electricity-driven to gas-driven technologies on the side of the users – be it via household technology or production machinery – or the other way round. As long as the shift is only marginal this will probably not affect the regime structure and the interactions between both. However, in the case of a far reaching shift from one dominant regime to another, changes in the internal structure as well as the structure of interactions between regimes are to be expected. Furthermore, markets will change and thereby also linkages with regimes fulfilling complementary functions.

A second type of transformation would be a shift from mainly competitive to more complementary relations between two regimes. Whereas regimes fulfilling a similar societal function compete on the one hand for common markets, at the same time this opens up a potential to fulfill jointly a common societal function. Quite often regimes competing at one point are functionally coupled at others fulfilling a certain function complementarily. In the course of a shift from competitive to more complementary relations new functional couplings are to be expected. In the utility sector an increasing use of gas as primary energy carrier in electricity generation could be an example. A much more radical dynamic in this direction would be a rather tight coupling of electricity, gas and the sewage system in the course of a potential transformation path leading to highly decentralized systems. Here the endpoint could be the merging of until now fairly separate utility regimes into a common larger utility regime.

5.3.3 Transformations on the basis of complementary relations

Transformation processes on the basis of complementary relations rely on functional couplings. Partly these are indirect interactions between regimes via common complementary regimes, e.g. certain use regimes. This could be an increase in the gas or electricity consumed because of an increase in the use of hot water, or, just the other way round, if less water is consumed, because energy is to be saved. A similar case is an increase in the use of electricity following the spread of new telecommunication applications (Huser/Aebischer 2002; Büllingen/Stamm 2003).[12] These use regimes are themselves coupled with other regimes, for example the regime of room heating and cooling is coupled with the regime of housing. Therefore major changes in the housing regime may indirectly affect utility regimes.

As mentioned above, complementary relationships often lead to co-evolutionary dynamics. Utility regimes and a number of its use regimes, in the private as well as in the industrial sector, could only develop conjointly as has been illustrated in historical studies. This type of dynamics typically goes along with a transformation or gradual emergence of interactions.

An important example may be illustrated by demand side management, an orientation of demand following supply, because this implies a stronger interaction between utility and use regimes, either based on technical, institutional, knowledge or value elements or some combination of these. These changes would imply considerable changes of the provider-consumer-relationship in the respective utility regimes (Chappels et al. 2000; Van Vliet 2002). A rather extreme version are concepts based on the possibility for supply side actors to actively turn on and off consumers of electricity (Kets et al. 2002). A development in this direction could be a correlative to an overall development in the direction to a decentralisation of utility systems.

6. Conclusion

In the present chapter, we have shown how transition theory might be fruitfully applied in order to discuss ongoing transformations in the utility sectors. The analysis of landscapes, regimes and niches helps to focus on stabilizing forces and to develop an integrated view of processes spanning consumption, production and regulation in order to identify future development paths, barriers and windows of opportunity. This step is an important precondition for identifying and assessing more sustainable futures of these utility sectors.

However, the concepts as expounded in the literature had to be broadened and modified in some important respects: First, we have enlarged the focus on technologies in order to include broader socio-technical transformations. As a consequence niches are not only identified for new technologies but also for other

[12] In the case of utility regimes the number of complementary use regimes is fairly large, so that an analysis of the role of complementary regimes for transformation processes in the utility regimes has to start by a selection of those complementary regimes that are likely to have a considerable impact on transformation dynamics of the utility regimes. This could be because of foreseeable internal dynamics and a strong coupling to the utilities, e.g. because they consume an important amount of the produced electricity, gas, water or telecommunication services.

innovation processes with a stronger focus on institutions, preferences and regulations.

The analysis of current transformation patterns in the utility sectors showed that non-marginal changes are possible in three domains: (i) a fundamental change in the technological logic of utility production and distribution. In former times orientation was focusing on economies of scale coupled with capital intensive material infrastructures connecting locations of production with locations of consumption. Recent developments show potential for more decentralized and flexible systems of generation and provision. (ii) Conjointly with market liberalization a fundamental break with user conceptions on the side of the utilities may be expected. Thus customer and service orientation may increase and gradually replace the former company logic which is more strongly based on technological necessities than on user needs. (iii) As a combination of the first two transformations, interactions and relationships between the utility sectors have the potential to change fundamentally. Therefore the delineation of regimes may undergo quite radical transformation and this may have substantial consequences for the environmental impacts of these economic sectors.

The analysis of the three major realms of change may be undertaken by discussing processes at the three levels of landscapes, regimes and niches. However, the theoretical apparatus has to be further specified in order to fit the specific needs. First, interactions between regimes have to be taken into account and their joint dynamics have to be analyzed. We proposed a concept for analyzing these interactions. Secondly, depending on the degree by which these transformations take shape it will be necessary to have a closer look at various patterns of regime transformation rather than to exclusively focus on ideal type transitions, leading to the substitution of a dominant regime by a new one.

The present conceptual analysis will be empirically applied in the context of a currently running research project in Germany. The goal of this project is to develop shaping strategies for long-term structural changes in utility sectors. Therefore it is necessary to identify possible futures for the utility sectors electricity, gas, water and telecom in Germany over the next 20 to 25 years. Emphasis is put on transformation potentials leading to more sustainable utility regimes. In this context, we have developed overarching scenarios for the four sectors conjointly with experts from utilities, governments, consumer and environmental NGOs and will analyze transformation paths which could ultimately lead to more sustainable futures. The present theoretically oriented analysis will therefore be brought to fruition for the interpretation of these processes.

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