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DECENTRAL WASTEWATER INFRASTRUCTURE:

CHARACTERISATION AND OVERCOMING PATH DEPENDENCIES BASED ON A TECHNICAL INNOVATION SYSTEM ANALYSIS

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6.1 Introduction

The centrally organised disposal of wastewater in Germany is a strongly regulated field for several reasons: because it is a public service, on the one hand, and because of its monopolistic character on the other. Innovations here are triggered and pushed by different actors, some of whom belong to the regulating authorities, some to the private sector. This applies to research as well as to the development and diffusion of the relevant technologies. The existing wastewater infrastructure has proven to be very innovative over the past decades with respect to various challenges, but the limits of its adaptability are reached if the underlying structure of the system is at stake, as is the case with demographic or climate change. Elements of a decentral infrastructure which could improve adaptability in the face of these major challenges and decrease uncertainty are only diffusing very slowly. This is valid in a technical-scientific sense, but also with regard to the actors and the framework conditions.

Based on the concept of a technical innovation system, we describe the factors which support or hinder innovations in the field of decentral wastewater infrastructure. In doing so, we refer especially to the innovation system functions listed by Bergek et al. (2008) and Hekkert et al. (2007). In addition to this, we draw particular attention to the characteristic feature of radical innovations, which deviate from already established technology paths and therefore may be subject to lock-out effects which hinder their further diffusion in spite of their principal suitability (Sartorius and Zundel 2005).

After describing typical actors and the specific framework conditions of wastewater disposal in general and of decentral wastewater disposal in particular (in Section 6.2), we show (in Sections 6.3 and 6.4) how path dependency and lock-in effects arise at the expense of decentral infrastructure alternatives and (in Section 6.5) how at least one of the obstacles can be overcome by re-organising property and utilisation rights and how this is accompanied by changes in the innovation system. The conclusions (in Section 6.6) round off this contribution.

6.2 Background

The original purpose of a centrally structured sewer system is to collect feces and wastewater of all kinds and to transport these away from residential areas. In addition to this, in order to avoid damages to the environment, the system is fitted with (central) sewage treatment plants which treat the wastewater, removing unwanted organic substances, nutrients and trace substances before discharging it into water bodies. The system of sewers not only represents the largest part of the required investments. Its planning and design also have to take into account all the eventualities of future developments because of its expected service life of more than 50 years. These include, among other things, demographic developments in the population being served and changes in water consumption and the profile of pollutants to be transported. In combined wastewater and storm water sewers, this also involves the changed frequency and intensity of heavy rainfall and storms due to climate change and the associated limits to their performance capacity (Koziol et al. 2006). Substantial adaptation costs or sunk costs may arise in the case of larger deviations from the originally planned concept. This cost drawback on the part of the central sewer system is offset by positive economies of scale effects at the sewage treatment plants, which allow more advanced treatment processes to be implemented at a given specific cost in larger plants.[1] The high capital cost of sewers is relativised from the viewpoint of the individual user if they are used to dispose of the wastewater of a large number of people in more densely populated areas. Another advantage from the viewpoint of the operators of the wastewater infrastructure is that it is easy to check whether the system is functioning correctly because this can be done centrally. The latter is less an economic and more of a political argument that has to do with the public welfare function of the state in the context of environmental protection and sustainability in general and the treatment of waste and wastewater in particular.

Unlike central wastewater infrastructure, the decentral alternative manages to collect the wastewater without a broad network of sewers. Instead, the wastewater from individual houses or small groups of houses is treated on-site with the help of small-scale wastewater treatment plants (SWTP) and subsequently discharged into a water body or allowed to seep away. The purification performance of these plants corresponds in principle to that of small central sewage treatment plants; the stricter standards of larger treatment plants, especially with regard to nutrient elimination,

1 This advantage is used by the legislator to set higher requirements for larger plants.

can also be met if advanced upgrading measures are applied. Small-scale wastewater treatment plants have therefore been recognised as equivalent to central treatment plants in line with Annex 1 of the German Wastewater Ordinance (AbwV) since 2002. Due to their very nature, SWTP are obviously not able to realise economies of scale to any significant extent, so that they are initially more expensive than central plants for the same level of performance. Up to a certain degree, they can make up for this drawback via increased numbers and the lack of sewers, so that at least in sparsely populated rural areas, decentral sewage treatment plants are more economical than their central counterparts. SWTP also have advantages if additional wastewater disposal capacities would have to be constructed in more densely populated areas because the existing infrastructure has reached its limits, or because it is becoming too expensive to operate a central infrastructure in regions with a shrinking population.

Table 6–1: Regional distribution of the population connected to small-scale wastewater treatment plants in Germany in the years 2001, 2004 and 2007

	2001		2004		2007	
Federal state	**1000 p.e.**	**%**	**1000 p.e.**	**%**	**1000 p.e.**	**%**
Baden-Württemberg	69	0.7	62	0.6	53	0.5
Bavaria	561	4.5	470	3.8	407	3.3
Berlin	2	0.1	2	0.1	–	–
Brandenburg	132	5.1	93	3.6	88	3.5
Bremen	0	0	0	0	0	0
Hamburg	–	–	6	0.3	5	0.3
Hesse	18	0.3	16	0.3	14	0.2
Mecklenburg-West Pomerania	270	15.3	241	14.0	205	12.2
Lower Saxony	516	6.5	482	6.0	454	5.7
North Rhine-Westphalia	480	2.7	426	2.4	364	2.0
Rhineland-Palatinate	28	0.7	20	0.5	14	0.3
Saarland	7	0.7	7	0.7	4	0.4
Saxony	493	11.2	369	8.6	334	7.9
Saxony-Anhalt	337	13.1	233	9.3	166	6.8
Schleswig-Holstein	171	6.1	159	5.6	147	5.2
Thuringia	216	9.0	184	7.8	179	7.8
Germany	3301	4.0	2769	3.4	2435	3.0

Note: p.e. = person equivalent
Source: StaBuA (2003; 2006; 2009)

In this respect, there are no reasons why both alternatives should not coexist in accordance with their relative merits. However, if a more detailed analysis is made of the figures listed in Table 6–1 showing the number of persons connected to SWTP, it is evident that there has been a steady decline in every German federal state since 2001. The question has to be asked whether the economically viable use of SWTP is actually limited to a share in the range of single-digit percentages which is where the figures are headed at the moment. That economic aspects are possibly not solely decisive is indicated by the fact that in some – but not all – non-city states shares of well below 1 % are reached, even though larger shares of the population here live in areas in which a central connection is much more expensive than the decentral option.

6.3 Lock-in effect due to sunk costs

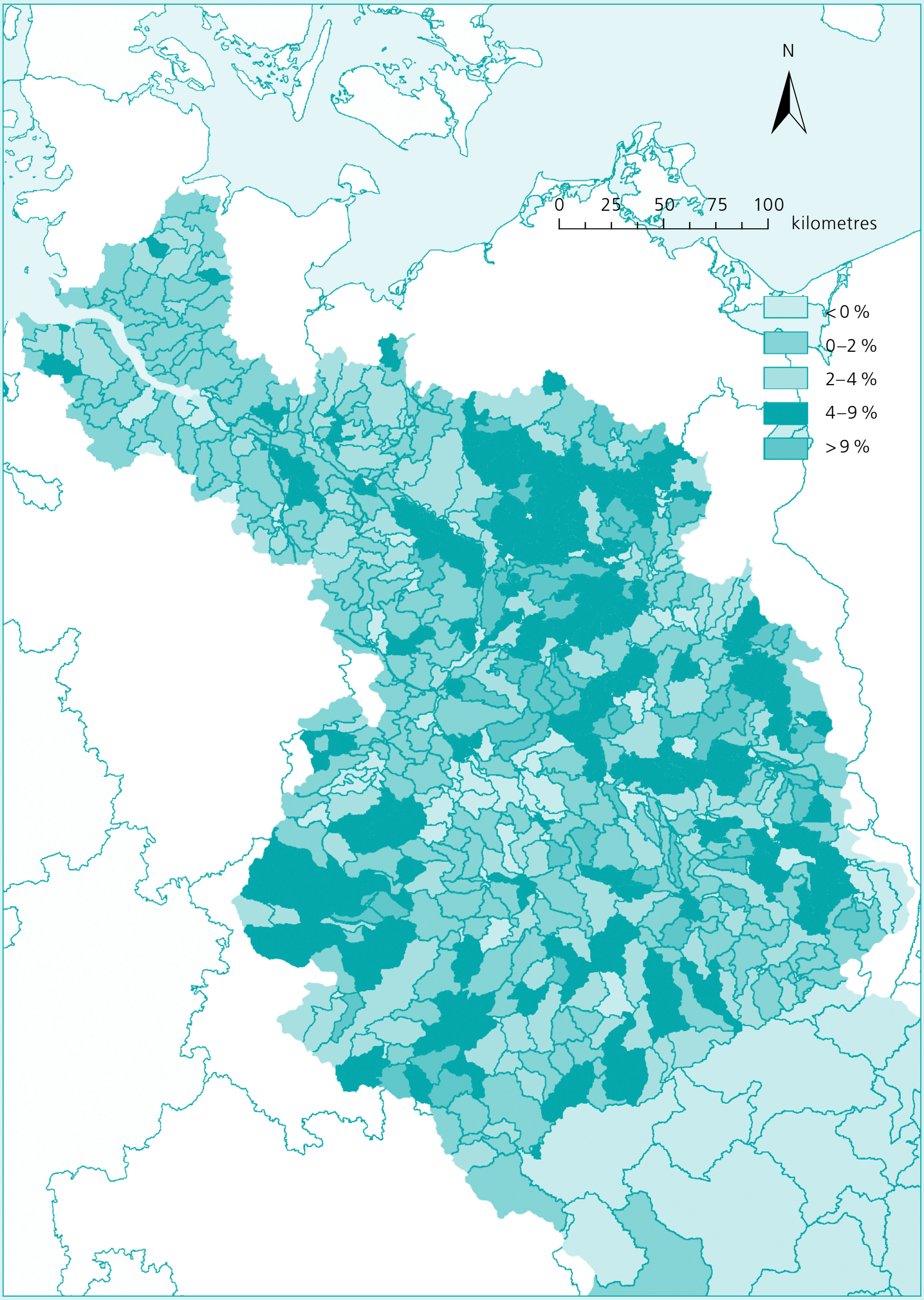
According to the comments made in Section 6.2, central wastewater treatment and SWTP are basically substitutes from a technical point of view. There are also no technical-economic reasons for a lock-in effect, i.e. the wider use of one of the two alternatives does not systematically preclude the other (Arthur 1988; David 1985). SWTP are neither dependent on additional (network) infrastructure which still has to be constructed, nor are there any technical incompatibilities between the decentral and the established central variants (Zundel et al. 2005). In order to confirm (or refute) the existence of a possible lock-in effect in favour of central wastewater disposal, it is shown first how SWTP would spread geographically if their use were based predominantly on technical and economic criteria. The INNUWIM (Innovation in Urban Water Infrastructure and Management) model is used for this purpose. This model was applied by Sartorius et al. (2011) to extrapolate the development of the wastewater infrastructure and its impact on nutrient emissions in the Elbe river basin up to the year 2020. As Figure 6–1 shows, the expansion of SWTP is mainly concentrated on Brandenburg. Other regions with significant but more moderate growth exist in parts of Thuringia, Saxony and Mecklenburg-West Pomerania. The average growth rates of the federal states concerned, which are presented in Table 6–2 up to the year 2020, confirm this impression.

Table 6–2: Comparing the stock of SWTP in the non-city states of the Elbe river basin with the increase predicted until 2020 using the model

	Stock (%)[2]			Growth (%)[2]
Federal state[1]	**2001**	**2004**	**2007**	**2004–2020**
Brandenburg	5.1	3.6	3.5	4.1
Mecklenburg-West Pomerania	15.3	14.0	12.2	1.7
Lower Saxony	6.5	6.0	5.7	1.1
Saxony	11.2	8.6	7.9	1.6
Saxony-Anhalt	13.1	9.3	6.8	0.7
Schleswig-Holstein	6.1	5.6	5.2	0.7
Thuringia	9.0	7.8	7.8	3.1

SoaBuA (2003; 2006; 2009); own calculations
1 Excluding the city states of Berlin and Hamburg
2 Ratio of the number of (additional) population connected to SWTP to total population

Figure 6–1: Ratio of the increase in persons connected to SWTP to the total population in the period 2004 to 2020 in the German part of the Elbe river basin



Sources: StaBuA (2003; 2006; 2009); own calculations

If mainly economic-technical criteria were decisive for the construction of SWTP, then there should be a large stock of them in federal states with high growth potential, whereas low potential should be accompanied by small stock figures. If the stock of SWTP in a particular state is higher than expected based on the potential, in the new federal states (i.e. states of the former GDR), this might also be related to the fact that decentral wastewater disposal was much more widespread in the former GDR, including the acceptance for certain malfunctions, than was the case in the FRG at the same time. This appears to be particularly the case for Saxony-Anhalt, since the stock here was comparatively high, particularly in 2001, in spite of the low potential. This relatively high stock, however, had dropped by almost half, by 2007, which indicates that, wherever possible, preferably the most up-to-date figures should be compared with the potential. Against this background, the state of Brandenburg particularly stands out, as the lowest numbers in terms of stock are set against the highest potential. There seems to be the tendency in Brandenburg to keep the stock of SWTP lower than seems plausible from a technical-economic perspective in other German federal states.

One reason for this could be the desire to achieve the highest possible capacity use of the central sewage treatment plants in view of the large investments made after reunification in expanding and upgrading the wastewater infrastructure. Operating central sewage plants with an extensive network of sewers which supply the wastewater is associated with a fixed cost share of up to 75 % (BDEW 2008). Every resident, disposing of wastewater using a SWTP instead of connecting to the existing central wastewater disposal system, would reduce the revenues of the waste disposal company in proportion to the amount of wastewater no longer treated centrally. The costs for the company, in contrast, would only be reduced by one quarter which would result in a considerable shortfall in their budget. In order to prevent residents withdrawing from using public wastewater disposal facilities, a mandatory connection and usage policy is practiced in Germany. Accordingly, wastewater producers who can be connected to public wastewater infrastructure at reasonable cost in fact have to connect and dispose of their wastewater there. In Brandenburg, this mandatory connection and usage policy is enforced with particular stringency because oversized sewage works were authorised and constructed after reunification, which are now underutilised and generating high costs. The enforcement goes so far that houses which are already connected to a SWTP and whose inhabitants refuse to comply with the mandatory connection to the central system are forced to do so by order of the police (NN 2008).

Even if mandatory connection and usage and its especially strict enforcement seem to be primarily responsible in Brandenburg for the contradiction between the high growth potential and the low actual stock of SWTP, this still does not necessarily indicate a lock-in effect. Different forms of one institution in different federal states are more likely to indicate only the competition of two technologies under different framework conditions. If the conditions for competition change, then the result changes too. At this point, therefore, it cannot be assumed that there is really a systematic basis in favour of the established technology as described by David (1985). However, if the reasons for the different forms of the connection compulsion are investigated, it can be concluded that the investments in excess capacities of municipal (central) sewage plants represent sunk costs to a large extent, mainly on account of these plants' long service lives of usually more than 50 years, which the operators of the infrastructure then try to reduce to the greatest extent possible. Sunk costs therefore represent the real cause of the contradiction and may very well be the reason for a lock-in effect (Zundel et al. 2005).

6.4 Lock-in effect due to institutional obstacles

Unlike the eastern federal states, sunk costs cannot be the reason for the low share of SWTP in the non-city states of Baden-Württemberg, Hesse, Rhineland-Palatinate and Saarland. Neither is any other economic-technical cause immediately apparent. It can therefore be suspected that features in the actor structure or the framework conditions are responsible for the low diffusion of SWTP. To investigate this in a more detailed analysis, we use the technical innovation system approach (TIS) of Bergek et al. (2008) and Hekkert et al. (2007). This approach is based on the idea that technical change in general and innovations in particular are influenced by many actors and framework conditions, especially institutions. These can – depending on how they or their characteristics are affected – influence the innovation process either positively or negatively. Furthermore, it has to be considered that the actors can even influence how framework conditions are shaped, depending on their own interests and influence. Depending on the type and extent of the possible impediments to an innovation, usually a path dependency, but frequently also a lock-in effect can be determined. The latter is particularly likely if a whole new technical approach is being pursued which does not build on existing components of the established system. In contrast to the *incremental* changes along established technology trajectories (in the case in point: central wastewater disposal), we then talk about *radical* innovations (Dosi 1982, p. 158f.). In the following, we apply the TIS approach to wastewater infrastructure and specifically to the introduction of SWTP. The TIS approach of Hekkert et al. (2007, pp. 421ff.) covers the following seven functions which are viewed as essential for the formation and diffusion of innovations:

(1) Entrepreneurial activities form the core of the innovation process. The entrepreneur recognises the opportunity for an innovation, collects resources to develop it further and decides at various points (under high uncertainty) whether it makes sense to continue or not. In the case of decentral wastewater treatment, considerable progress has been made in the development of SWTP and the treatment processes implemented in them. So far, the risk involved has been limited, since most parts were able to draw on existing components and the investments in the plants are relatively low. There was a greater need for adaptation concerning the variability of wastewater volume and the resulting higher demands with regard to robustness. In the future, it will be important to be able to conduct (remote) checks that SWTP are functioning correctly and simultaneously to improve their economic efficiency. This will require

the production and, where necessary, operation of larger numbers of SWTP which will probably lead to an increased risk.

(2) Knowledge development, i.e. learning, forms the basis of the innovation process and represents its most essential resource. Its institutionalised form is known as research and development (R&D), which itself requires investments in material, human and eventually financial resources. In the case of SWTP, the more basic part of this knowledge has already been developed in private enterprises and public research institutes, like the *Prüfinstitut für Abwassertechnik* (Testing Institute for Waste Water Technology, PIA) and at several university institutes. The same types of enterprises and institutes, albeit in somewhat different research areas, are involved in developing remote control capability for SWTP. As far as innovative ways of operating (a larger number of) SWTP is concerned, a very different type of non-technical knowledge needs to be acquired, whose development will probably involve quite different actors. We will go into more detail later.

(3) Knowledge diffusion in networks is essential in so far as, except during the early phases of some inventions, knowledge creation involves the collection and recombination of the ideas and experiences of various actors who are somehow related to the innovation considered. Beyond the companies and institutes directly involved in the development and operation of SWTP (see last point), this includes institutes concerned with standardisation and testing like PIA and the *Deutsches Institut für Bautechnik* (German Institute for Construction Technology, DIBt), which measure and compare performance according to commonly agreed, unified standards and thus enable the comparative evaluation of different technical approaches. Another important multiplier for knowledge concerning SWTP is the *Bildungs- und Demonstrationszentrum für dezentrale Abwasserbehandlung* (Training and Demonstration Centre for Decentralized Sewage Treatment, BDZ), which compares the performance and operating experiences with different types of SWTP and helps to disseminate the knowledge gained among the manufacturers (giving them the opportunity for improvements) as well as the users. Knowledge diffusion is, however, not limited to manufacturers and users. It includes both legislators and administrators (i.e. the wastewater authorities), which set the rules and monitor and control the facilities once they are installed and in operation.

(4) Guidance of the search refers to the direction in which R&D ought to proceed and needs to be supported accordingly. This is especially true in the context of environmental innovations where the legislator sets compulsory rules, which can only be met by employing specific technologies. For SWTP the respective basic requirements are given in Annex 1 of the Wastewater Ordinance, which states the maximum allowed emission limits for BOD, the nutrients N and P, and for the sterility of the runoff under various conditions. It should be noted in this context that these limits are not simply set top-down by the authorities, but that they are developed in an exchange of opinions between stakeholders as to what should be done with regard to safeguarding human health and protecting the environment and what can be done from the technical and economic perspective (see knowledge network function, above). Less

basic innovations related to SWTP which include the extension of their basic functions by remote monitoring and control are not guided directly by the above mentioned legislation, but by the attempt to comply with it as economically as possible.

(5) Market formation is a basic aspect of innovation as it includes the entire progression of a new product from its invention to appearance on the market. Entering the market requires much more than acquiring knowledge and solving technical problems. Building and expanding manufacturing capacities requires substantial financial resources and human capital needs to be restructured in order to market the large quantity of production output. As a market for SWTP already exists, its basic formation appears to have taken place already. However, although its actual market share is rather small, it seems to be declining rather than increasing (cf. Table 6–1). From this perspective, the questions arise whether the market is indeed really so small and which parameters could be changed in order to expand it. This paraphrases the basic question tackled in this contribution, which we will look at in more detail later. Another argument usefully discussed at this point is the need to design a market formation strategy. All more or less radical innovations which are not directly related to the established technology paradigm tend to be more costly, especially when they first enter the market, because they have not yet been able to benefit from economies of scale and learning-based cost degression. In order to still gain a foothold in the market, it is advantageous to identify market niches where at least a limited number of customers are willing to pay an initially higher price for the innovative product (Kemp et al. 1998). For SWTP, this is the case in remote regions where households can be connected to the central sewage system only at very high costs. In some (relatively well-off) federal states like Baden-Württemberg, the authorities are willing to pay the higher price for the central sewage connection in rural regions, whereas in less wealthy states, like Saxony, they are not. Accordingly, the remote regions of Saxony do indeed represent a market niche for SWTP. However, while the existence of a market niche strongly supports the diffusion of an innovation, this condition is not sufficient on its own.

(6) Resource mobilisation as a requirement for the development and diffusion of (environmental) innovation has already been emphasised in various contexts: material, financial and human resources. As SWTP are not high-tech, their material needs are not sophisticated and the mobilisation of the respective resources is not a problem. Financial resources are also not limiting, because SWTP facilities are not very expensive and the costs are met directly by the users. This latter issue might change if a large number of devices were bought and operated by a single company and offered as a service to the customers. In this case, this company would face a large upfront investment with only long-term (and thus risky) returns. We will see later how this situation may be overcome.

(7) Creation of legitimacy is a very important aspect in the context of SWTP employment, although this may not seem so relevant at first. Legitimacy basically refers to the motivation to employ a technology. In most cases, innovations cause benefits and, at least for some stakeholders, costs. The benefits are often uncertain as is the

overall success of the innovation. From this perspective, it is legitimate to ask whether an innovation should be supported at all by the government. With respect to SWTP, legitimacy appears to be less of a problem, since the need for wastewater treatment is established in the *Wasserhaushaltsgesetz* (Water Management Act, WHG) and the related Wastewater Ordinance. Moreover, SWTP have been around for quite a while now and used to be even more widespread in the past. Beyond these basic arguments, however, the acceptance of SWTP is ambiguous from different perspectives. While SWTP in their current form may be acceptable to users, water authorities consider them problematic unless specific safety measures are implemented. Since these measures are costly, their application decreases user acceptance of SWTP. One way to resolve this conflict could be a substantial change in how SWTP are operated, but this also involves certain challenges which we will discuss in the following.

The legislator makes the basic assumption that the run-off discharged by SWTP meets the stipulations of the German Wastewater Ordinance, and that SWTP operators i.e. the households are complying with them as long as the plant has a general permit and is maintained properly. However, this turns out to be an invalid assumption because of weak control and the low level of professionalism when operating the plants. Therefore the political reservations have less to do with the SWTP technology itself and are directed more at its incorrect operation by private households (cf. e.g. BaWü 2002). The existing studies on this topic seem to substantiate this: Based on studies of several thousand SWTP as well as surveys of water authorities and the manufacturers of SWTP, Otto (2000) found that, in 1996, the 9.5 % of the population not yet connected to the central system produced up to a maximum of 44 % of the total resident-related COD emissions from wastewater treatment plants. A study in Bavaria by Schleypen (2001) found that 7 % of the population discharged 70 % of the organic waste. According to estimates of Baden-Württemberg's Ministry for the Environment and Transport, the actual purification performance of SWTP is lower than central facilities by a factor of 8 to 10, in spite of the fact that they are fundamentally equivalent in technological terms as stated above. A study by Eggert (2007) based on data from maintenance companies confirms this suspicion: In 2004, only 62 % and in 2007 only 68 % of the SWTP checked met the requirements of the German Wastewater Ordinance. As a result, the federal states Baden-Württemberg, Hesse, Rhineland-Palatinate and Saarland have decided that they will do without SWTP as much as possible, in spite of their status of non-city states and the associated additional costs2 (cf. Table 6–1).

2 The Environmental Ministry of Baden-Württemberg regards 25,000 euros as reasonable costs for those obliged to be connected to the sewer system (BaWü 2002). In addition to this, the state provides a subsidy of approx. 4,000 euros per connected person (BBU 2006). The total costs of being connected to the central sewer system for a 4-person household, therefore, amount to roughly 40,000 euros, which are considered to be acceptable. These are set against the costs of approx. 6,000 euros for a small-scale wastewater treatment plant with a 4-person capacity (investment costs including installation), although financial support of small-scale treatment plants is not planned. Obviously, Baden-Württemberg is prepared to spend quite a lot on central wastewater disposal and for its citizens to do the same.

In the other non-city states, the authorities have no reservations about the use of SWTP if the connection to the central sewage network is more expensive. Saxony, Thuringia and Mecklenburg-West Pomerania even support their construction under these conditions (SMUL 2007; MUMV 2007). And North Rhine-Westphalia was especially active in the research and further development of SWTP from the 1990s up to the middle of this decade. And yet the share of the population connected to SWTP still dropped continuously and significantly even in these federal states from 2001 through 2004 up to 2007, as can be seen in Table 6–1. This cannot be due to the basic performance of SWTP. It could mean, however, that SWTP are less attractive today compared to municipal wastewater disposal for other reasons. This must take into account the fact that SWTP were rarely serviced in the past and therefore were hardly able to function properly 10 to 20 years after their installation, but at the same time did not cause any costs. Today, in contrast, the operators, i.e. usually the users themselves, are obliged to enter into a maintenance contract and the SWTP have to undergo to two to three service and maintenance checks each year, depending on the type. This upkeep on its own is usually just as expensive as, or even more expensive than, the sewage rates which would have to be paid for a connection to the municipal wastewater disposal system – even without including the other operating costs and other inconveniences. This argument also indicates that the decrease in SWTP is not due to a lock-in effect, but rather to a decrease in their attractiveness.

The obvious question here is whether these expensive inspections two to three times a year are the only way to maintain the performance capacity of SWTP, which are much more efficient today than they were 10 or 20 years ago? Other regulations are also conceivable which would be less costly and/or more user-friendly and which could increase the attractiveness and thus the diffusion of SWTP. In this context, it should be asked what potentials new business models can offer to overcome the path dependency diagnosed above.

6.5 The potential of new business models

In order to answer this question, a study was conducted, together with the Abwasserzweckverband (AZV) Leisnig (local wastewater treatment authority), to examine the impacts of a business model for operating SWTP (AZV Leisnig 2010). Some parts of this model have already been realised and others are still in the process of being implemented. The region administered by the AZV is in Central Saxony and covers an area of 95 km^2 with 48 districts. With the exception of the town of Leisnig, the region has a rural structure.

The main impetus for the AZV to become involved with new concepts for operating SWTP was given by the forthcoming European Water Framework Directive, which is due to be implemented by 2015, and by the state of Saxony's support in the form of the relevant funding programmes. Because it was not possible to expand the central wastewater treatment as required by the WRRL, on account of the high cost of constructing sewers in the rurally structured region of the AZV, it was decided to first check the performance of the existing SWTP in order to determine how far away they are from the state of the art in this field.

To this end, the AZV Leisnig first offered maintenance contracts for SWTP. During the course of these service inspections, it quickly became clear that many SWTP are in a poor condition, which can be traced back to errors made during installation, operation and servicing. Because of the insufficient expertise of the private households and the lack of advice, the SWTP types selected frequently did not comply with the daily operating requirements. On top of this, the decision about wastewater disposal is dictated by price rather than quality considerations in many households and, on the part of the manufacturers or operating partners, successful sales seem to be the main driver rather than the suitability of the installation to solving the respective wastewater problem.

6.5.1 Improving the available information and acceptance

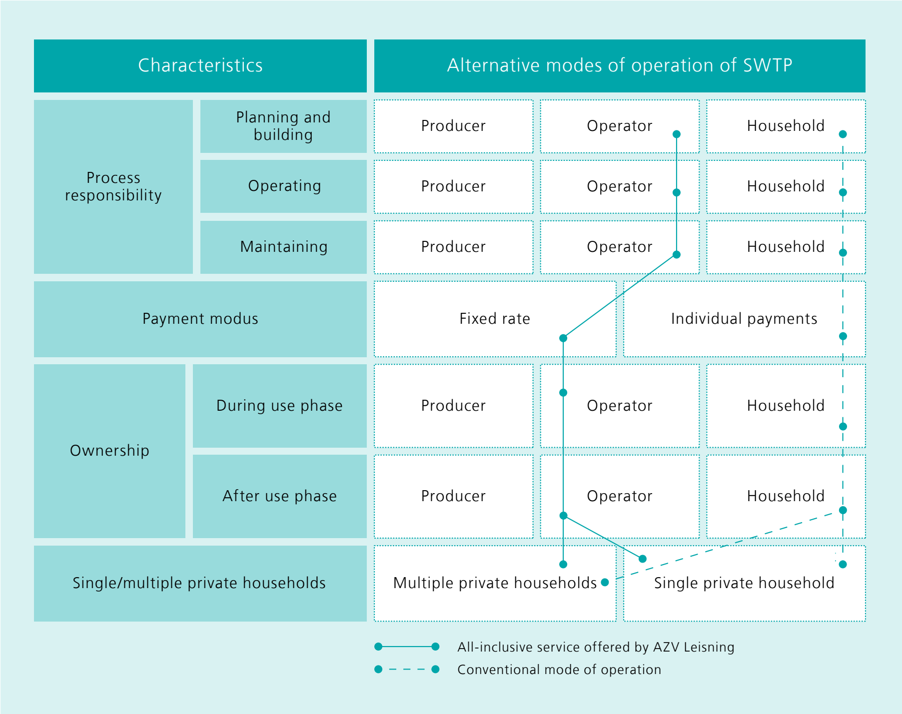
This is why the AZV set itself the goal of gaining direct access to the SWTP by offering the operating scheme which also gives them greater control of the installations' condition. Another goal is the stronger integration of SWTP manufacturers. Direct access and individual control of the SWTP is also important in the context of complying with the threshold limits for the run-off from SWTP, because it is impossible to localise the cause of increased measurement values at sewer level without knowing the condition of each discharging SWTP. Since the AZV has to answer to the water authority for complying with effluent standards, this is another reason for the strong interest in having direct access to the SWTP. Another argument for developing a new business model is the high investments for modernising the stock of plants: a 4-person household has to reckon with between 5,000 and 10,000 euros to build a new SWTP; retrofitting an existing 3-chamber septic tank with a biological stage costs about 3,000 to 4,500 euros (Sachsen-Anhalt 2002). Especially in a structurally weak region with high unemployment like that administered by the AZV, many property owners cannot afford such an outlay – in spite of the state's funding programme. Therefore the wider population is also increasingly concerned with the problem of wastewater disposal and called upon the AZV to help develop suitable solutions.

The basic features of the business model offered by the AZV are listed in Figure 6–2 and compared with conventional SWTP operation.

6.5.2 Adapting use and property rights

As can be seen in Figure 6–2, the so-called "All-inclusive service" package endows the AZV Leisnig with the responsibility for planning, building, operating and servicing the SWTP and entering into a private law waste disposal contract with the owner of the property to this end for an indefinite period. The AZV is paid a fee by the property owner for these services. The SWTP remains the property of the AZV during and after the end of the contract period. Two variations of the business model can be distinguished, using the criterion "exclusivity of use". These can be regarded as the

Figure 6–2: Comparison of the conventional model for operating SWTP with the "All-inclusive service" offered by AZV Leisnig



Source: Lay et al. (2003)

main components of the total concept for adapting wastewater disposal to the new legal framework conditions: group solutions and individual solutions.

Implementing group solutions (with 12, 40, 60 or 80 residents) assumes that several buildings in a village are connected to a decentralised group treatment facility. Since the SWTP are built on a publicly owned plot of land, the AZV can access them at any time (e.g. for maintenance and inspections). After initial reservations, these group solutions have since become highly accepted by the population, largely because they are not operated as separate public installations, but are integrated into the central wastewater system. This has the decisive advantage for the users that they are placed on an equal footing with households connected to the central system in terms of the fees paid.

If the costs for connecting a property to the central wastewater system or a decentralised group solution exceed a certain threshold, the AZV wants to offer individual solutions. In contrast to group solutions, in which the plant is constructed on a neighbouring piece of public land, in an individual solution the SWTP is built directly on the property of the wastewater producer. This means that the AZV has to be allowed regular access to the property in order to build, operate and service the installation.

Since this requires the property owner's consent, individual solutions – as opposed to a group solution – cannot be imposed via the connection and use obligation, but only through private law contracts. When drawing up these contracts, the property's specific conditions have to be considered, on the one hand, and, on the other hand, there is great uncertainty so far about the main influencing and cost factors such as, e.g. how liable the installations are to malfunction. In spite of this uncertainty, the contract conditions have to be attractive enough to motivate the property's owner to switch to the new business model.

Because the new business model of the AZV is still in an early phase of implementation, only a few reliable insights have been gained so far. Nevertheless, plausible indications can be found at this point with regard to the likely impacts on the innovation system of decentral wastewater disposal which are discussed below, based on the seven functions of the TIS approach used by Hekkert et al. (2007).

6.5.3 Impacts of the new business model on the innovation system

(1) Entrepreneurial activities: The AZV does not conduct any technology development itself and as a public institution works on a non-profit basis. This is why care must be exercised in using the term "entrepreneur" in this context. Nevertheless, within the strongly regulated field of wastewater disposal, the AZV still has a role to play which corresponds to the functional character of an entrepreneur in the sense of the TIS approach. Considerable pressure to change is exerted by the reforms in the regulative setting and the specific adaptation problems of the Association (rural region, structural unemployment), to which the AZV has reacted by designing its operating scheme. This is primarily an organisational innovation but brings technical adjustments in its wake. The AZV was able to follow up experiences from the pilot project "Dahler Feld" of the Lippeverband in North Rhine-Westphalia, where a similar model was realised as part of the AKWA research project for several households (Hiessl et al. 2007). Unlike this spatially highly limited and publicly funded pilot project, the AZV is taking on much higher economic and political risks by aiming to introduce the operating scheme throughout the entire administrative district.

(2) Knowledge development: The gradual implementation of the business model in the area administered by the AZV Leisnig results in learning processes taking place at different points in the TIS: In technology terms, new functional requirements of the installations are relevant, because the operator is attempting to operate a large number of installations at lowest possible costs and, among other things, wants to use remote monitoring to do so. In organisational terms, there is continued uncertainty regarding the concrete contract terms of the operating scheme. This uncertainty will only be able to be reduced over time as experiences are gathered with the actual operation of the installations ("learning by doing"). As Figure 6–2 clearly shows, in principle, there are alternative conceivable designs of the business model, e.g. by more strongly involving the SWTP manufacturers.

(3) Knowledge diffusion in networks: Diffusion processes take place both within the administrative district and within the network of decentral wastewater disposal

in Germany. Within the administrative district, the operating scheme of the AZV is regularly presented and discussed at public meetings, at which it is increasingly possible to refer to the experiences of pioneering users and early adopters. Within the network of decentral wastewater disposal, the knowledge generated by the AZV Leisnig will be passed on to the manufacturers of SWTP. Horizontal diffusion processes also take place at administrative level, because other wastewater associations will orient themselves on the approach taken by AZV Leisnig.

(4) Guidance of the search: The AZV Leisnig has positioned itself more centrally within the technical innovation system of SWTP by implementing the business model. By documenting, analysing and processing experiences made with the daily operation of several hundred SWTP, concrete technical requirements can be derived for the SWTP manufacturers, for example with regard to robustness, maintenance friendliness, modularity and remote monitoring and control, and the further development of SWTP technology can be pushed in terms of an association created for this specific purpose. The AZV is already actively influencing the manufacturers of SWTP and those producing remote electronic monitoring systems so that these are better matched and adapted to the operators' needs. The AZV uses public tenders as the primary means of implementing these requirements.

(5) Market formation: There is an associated shift in the responsibilities for procuring SWTP when switching to the operating scheme of the AZV Leisnig which results in a fundamental change in the market structure and the procurement process. While SWTP manufacturers have been used to selling their systems directly to the households or via agents, the AZV Leisnig now takes over the central procurement of the systems. Because it can be assumed that the AZV Leisnig has much higher expertise than the average private household, this results in a professionalisation of the procurement process which should impact the corresponding innovation processes. This development is favoured by the information asymmetries between vendors and buyers having less effect due to the changed setting, and by more specific requirements of SWTP performance being formulated by the buyer and demanded in public tenders.

(6) Resource mobilisation: Alongside private households, the German federal states also play a major role in mobilising financial resources. From the perspective of the federal states, operating schemes can contribute to more efficient use of the funds available for the construction of SWTP. According to the Förderrichtlinie Siedlungswasserwirtschaft (Guideline Municipal Water Management) (RL SWW/2009), the Free State of Saxony provides a basic grant of 1,500 euros (4 p.e.) for constructing a new SWTP with a biological purification stage and a basic grant of 1,000 euros (4 p.e.) for retrofitting an existing plant. If, for example, it is assumed that at present 458,000 residents are not connected to the central wastewater network in Saxony and that 80 % of these systems need modernising, then at least 91.5 million euros are required solely in the form of basic grants. The business model is able to achieve a much more efficient use of public funds because private households frequently invest in systems which do not meet their actual daily operating requirements, due to their lack of specialist knowledge.

Concerning the resource of knowledge, the new business model has the major advantage that AZV Leisnig is at home in the wastewater management sector and is able to draw on existing experiences in many regards (e.g. the treatment of wastewater in general and dealing with authorities and associations), which means that the optimisation of the business model can be expected in a relatively short time.

(7) Creation of legitimacy: From the perspective of the households, the first point to be made is that AZV Leisnig's offer has created an alternative to operating the system themselves. However, how each customer evaluates these two alternatives depends on many different factors. Because the business model of the AZV Leisnig means that all the work associated with operating the SWTP has now been shifted into the commercial sector, the benefits each household associates with such an offer depend heavily on the costs involved. AZV Leisnig has some leeway here as to whether it charges the households the total costs or only a fraction of them, especially where the individual solution is concerned. In the latter case, the rest would have to be borne by the community as a whole, meaning a general increase in the rates as a result. Because the additional costs are inevitable, it is likely that the early involvement of the citizens, e.g. in public meetings, will be a decisive factor in how the operating scheme is accepted.

6.6 Conclusions

This example of the decentral wastewater disposal of the AZV Leisnig clearly illustrates what David (1985) and Dosi (1982) understand as path dependency or technological paradigms. According to David (1985), path dependency describes a series of events in which the possible result is influenced by prior events. This means the longer a path has already been trodden, the lower the number of paths which could still be taken. Transferred to the actor network of wastewater disposal, this means that the actors' freedom of action becomes smaller, the more connections they have with other actors in the network. With technological paradigms, Dosi (1982) also alludes to the close link between innovations and the actors who develop, manufacture, operate, use or regulate them. In order to avoid a lock-in effect, everyone would have to change their actions in a coordinated manner, which is not very likely.

Two causes of a lock-in effect in wastewater disposal could be identified on the part of the central technology based on networks of sewers and large sewage plants and at the expense of small-scale wastewater treatment plants. One results from the long useful life of central sewage systems and sewage plants in combination with obvious oversizing and declining wastewater volumes, above all in eastern Germany. High sunk costs result in the case of switching to an alternative technology such as SWTP, which the operators try to avoid. The situation is made even worse by the fact that the upkeep of the central wastewater infrastructure is also associated with high overheads which further increase the sunk costs. This problem is now becoming very apparent in Brandenburg and the water supply companies here are attempting to limit their damages by strictly enforcing the connection and use obligation wherever possible. An escape from this lock-in situation is currently only foreseeable in locations where it is doubtful whether the central wastewater disposal is still able to function properly as a whole or in parts, for example, due to a further decline in the population and their specific consumption volumes. The sunk costs are then accepted here and parts of the central infrastructure are deconstructed and the wastewater of the remaining residents disposed of using SWTP (Koziol et al. 2006).

The other cause is related to the reliability of decentralised wastewater disposal, the associated costs and the level of acceptance resulting from these two issues. For SWTP to be able to hold their own against the established, central technology, it is not enough for them to be cheaper. They also have to be just as reliable, among other things, and should not be harder for their users to manage than the conventional technology. Several demands are being made here at the same time which would have to be coordinated and implemented by those very actors who are currently predominantly working with the central infrastructure. This presupposes a learning process which culminates in new business models, for example, like the "All-inclusive service" package offered by AZV Leisnig. In line with the strategic niche approach of Kemp et al. (1998), SWTP would become more and more attractive, due to learning effects on the part of providers, users and regulators and, as a result of this process, continually expand their niches. Over the course of this development, decentralised wastewater management would not completely replace its central counterpart but, in the long term, it would become a major, widely established component of the total system of wastewater disposal.

The deficiencies associated with private households operating SWTP and the regulative pressure exerted by the upcoming implementation of the European Water Framework Directive have resulted in the emergence of new business models for operating SWTP, which could accelerate this development. This is not only because political acceptance of decentral wastewater treatment is increasing, due to the resulting professionalisation, but also because the role of the actors and their links in the innovation system are changing substantially, due to the altered arrangement of property rights.

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