Water Management Towards Sustainability – An Indicator System to Assess Innovations[1]

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1 Introduction

Sustainable Development describes a long-term path for an economy or a part (e.g. a sector) of an economy that is consistent with particular – normative – criteria. While highly aggregated models often deal with just one indicator, namely consumption per capita, several indicators are necessary in order to describe a real path. The simple reason is that methodological problems and knowledge deficits impede among others a comprehensive monetary assessment of our doings at present and in future[2]. Therefore, the sustainability concept is frequently put in concrete terms by distinguishing economic, ecological and social aspects. Each of these three "pillars" in itself is often made up of a whole string of different aspects. Therefore the question arises what the idea of sustainability in context of water services means and by which indicators it can be expressed.

Beside the discussion of an exact definition of the term "sustainable water management", it has to be clarified how to reach this future requirement. In other words, those innovations should be realised that provide the highest contribution to the indicators chosen. Though policy makers need not necessarily know those, they should have a general understanding of the factors and (eco-political) instruments that induce firms to be innovative in a useful sense seen from an overall economic point of view. Ideally, it should be possible to convert those characteristics of innovation-friendly general conditions into indicators for sustainable innovation.

Thus, the aim of the paper is to make a proposal for a scheme describing innovations and their qualitative assessment with regard to sustainability (chapter 3). First we will outline the implications of the sustainability concept for the water services sector (chapter 2.1). Following that we will give

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1 This work is part of the interdisciplinary research project AquaSus. We greatly appreciate the support from the Federal Ministry of Research and Education. The views expressed are solely those of the authors

2 The title of Jessinghaus' (2000) paper illustrates this problem, it reads: „On the Art of Aggregating Apples & Oranges"

a brief overview of typical indicators of innovation before we merge the two concepts of sustainability and innovation (chapter 2.2). After outlining the indicator concept in chapter 3, we explore some empirical evidence for the German waste water sector. In this context it seems useful to discuss briefly the regulatory and institutional environment that distinguishes the waste water sector from other sectors (chapter 4.1). Then some results concerning the determinants of innovations that stem from a survey conducted among German firms providing waste water services will be presented (chapter 4.2). We close with some political implications (chapter 5).

2 Sustainable water management, innovations and their indicators

2.1 Indicators for sustainable water management

Water resources fulfil several functions for both the ecological and economic system. Therefore the corresponding allocation problem has a quantitative and a qualitative dimension. Besides, present uses can be accompanied by irreversible damages to water resources. Thus, in a first step, it is obvious to put the idea of sustainable water management into concrete terms by using the so-called management rules for natural resources (Daly 1990; Enquete-Commission 1994). According to these rules, water uses should take place only at rates less than or equal to the natural rate at which they can regenerate. On the basis of this management rule, further principles were formulated (table 1) that have been – at least essentially – adopted by different organisations like The Federal Environmental Agency (Brackemann et al. 2001) and the professional association ATV-DVWK (ATV-DVWK 2001).

Table 1. Principles of sustainable water management

Principle of sustainability	Content
Regional principle	Regional orientation in the management of water resources; avoidance of interregional externalities (definition of regions in accordance to hydrological criteria).
Integration principle	Water is to be managed in its context to other environmental media. Integrated view of ecological, social and economic demands of the concept of sustainability.
Polluter-pays-principle	Allocation of cost of water use according to the use of water resources.
Co-operation and participation principle	Sustainability as common task of state and society. Public participation in decision making.
Minimisation of resource use principle	Reduction of resource use and increased use of regenerative natural resources.
Precautionary or prevention principle	Avoidance of measures with high potential of damage and/ or risk. In practice: principle of minimisation, put down in the drinking water ordinance.
Point of pollution principle	Prevention of a release of harmful substances at the place where they emerge, i.e. no end-of-pipe technologies wherever possible.
Reversibility principle	Consequences of measures in the field of water management should be reversible whereever possible.
Intergenerational principle	Taking the interest of future generations into account.

Source: in accordance to Kahlenborn and Kraemer (1999); Brackemann et al. (2001)

Some of these principles like the precautionary and prevention principle are already important for the German water policy[3]. The regional principle got higher importance by adding to The Federal Water Act (WHG, Wasserhaushaltsgesetz) the obligations to meet the needs of the public water supply above all by local resources and to control the uses of water re-

[3] According to INGU (1999), five of nine principles can be found in German water management laws. Of course, a mention in water laws does not ensure that these principles will be adhered to everywhere in an appropriate way

sources on the basis of river basins. Although these principles give – compared to the management rules – a bit more detailed view of the sustainability concept, some questions remain unanswered. Firstly, even if every single principle would be self-explaning, well defined ecological objectives remain still the prerequisite for following them. To this end the EU Water Framework Directive (WFD)[4], which came into force at the end of 2000, sets new yardsticks (Kaika and Page 2002). The WFD has introduced the "good status" of water bodies as a general aim of water management. Member states are required to achieve a good surface water and groundwater status by 2015. This means that surface water bodies shall have a "rich, balanced and sustainable ecosystem and that the established environmental quality standards for pollutants are respected". While physical-chemical criteria are familiar in water management, the ecological criteria are what can be called an institutional innovation. For groundwater bodies, a good chemical quality as well as a good quantity state (abstractions less than or equal to the rate of recharge) are required.

These objectives and the other requirements introduced indicate that the WFD tackles the main threats to sustainability with regard to water bodies: over-abstraction and pollution[5].

Secondly, the principles do not refer equally to all three "pillars" of the sustainability concept. Economic and social aspects are hardly explicitly mentioned. A very complex demand is entailed in the integration principle, according to which water management should be based on an integrated view of ecological, social and economic aspects of sustainability. Up to now, all actions like the reduction of pollution and measures of groundwater protection have been subordinated to the objective to supply drinking water of high quality[6]. Especially economic aspects like cost efficiency

4 "Directive 2000/60/EC establishing a framework for the Community action in the field of water policy", adopted on 23 October 2000

5 These changes concern, among others, the switching to a water management based on river basins, the so-called combined approach, the introduction of the costs of environmental externalities into water pricing and an increased public participation while developing water management schemes (Kaika and Page 2002)

6 See for example Ministerium für Umwelt und Verkehr Baden Württemberg (2000) and Niedersächsisches Umweltministerium (2002). The states Lower Saxony and Baden Wuerttemberg have called commissions of experts who formulated concepts of a sustainable water supply. However, in Lower Saxony the experts failed to reach consensus about the appropriate principles and proposals for the State water policy. Additionally, they were strongly focused on

have played a minor role in the water services sector so far. Only recently, there is a growing debate about appropriate measures for enhancing the economic performance of the firms (cf. WrcPLC and Ecologic 2002; Ewers et al. 2001; Brackemann et al. 2000). Although this has not resulted in substantial changes regarding the regulation of the sector and the degree of competition between firms, it might be seen as the beginning of a new defining process of the objectives of water management.

In order to clarify the relative importance of single objectives (e.g. a good drinking water quality, low prices and sufficient conservation), mechanism of participation of the public could be further developed. Public participation is a general demand in the context of sustainable development. The requirements made in the WFD (article 14) are rather a first step in this direction than a comprehensive scheme of participation of the public in water management decisions. The WFD only requires measures of information supply and consultation, whereas active involvement of the public is encouraged but left to the discretion of the Member States (ENGREF et al. 2003).

In any case and irrespective of any deficits, further criteria and indicators are needed which specify both the principles and the other aspects of a sustainable water management. Even though a whole string of sustainability indicators does exist (e.g. OECD 1998; BMU 2000), there is no uniform indicator system in use. Instead, scope and contents of indicators vary depending on both the actor who draws up a report and the addressee the report is for. Thus, as a first step the indicators and their desired level that shall represent the objectives of a sustainable water management have to be chosen. As a starting point we can partly fall back on standards defined in the different directives, acts and ordinances. Changes of these indicators in the desired direction indicate the impacts of innovations for which the drivers shall be identified and likewise expressed by indicators.

2.2 Indicators of innovation

Studies dealing with indicators for innovation focus foremost on so-called primary players like universities, research institutes or firms which invent new products, technologies or materials, take out a patent for their innovations or sell their new products. In this context, typical indicators are expenditures in R&D, education level of the staff, number of publications and patents, or the share of innovative sales at home and abroad. This ap-

the conservation of water as a regenerative resource and failed to take into account other aspects of sustainability plies essentially as well to studies on environmental-related industries, i.e. industries which produce environmental friendly technologies, etc. The study of Gehrke et al. (2002), for example, presents mainly the following innovation indicators referring to water management: Publications on environmental science, patents for technologies of water purification, production of technologies of waste water treatment, indicators of trade (revealed comparative advantage, relative world market share), turnover of products and services for water protection, public expenditures on environmental protection and environmental research.

Typically these indicators of innovation inform solely about inputs in innovation activities or about outputs of these activities. What remains often unexplained is to what degree certain inputs determine the outputs. Besides, most of the studies do not deal with the impact of changes of output indicators on sustainability.

However, how fast and to what extent objectives of a sustainable water management will be reached does not only depend on the innovative performance of universities, research institutes and technology suppliers but also on the behaviour of the users of technologies of water purification and treatment. These users are, apart from industrial firms, water utilities whose main objective is to provide the public with drinking water and to run sewerage networks and sewerage plants rather than developing and supplying new products. Regarding the three phases of innovation, they contribute to the diffusion of new technologies rather than inventing them. Water utilities in Germany typically have – in contrast to some big French water firms – no inhouse research department, even though it is quite possible that we could find co-operations with universities or research institutes aiming, for example, at the first application ("adaption") of a new technology. Therefore, other indicators are required namely such indicators that describe and determine the innovative performance of a firm or other players within the innovation system respectively.

Indicators concerning the innovative behaviour of water utilities might be, for example, the

- number of co-operations with suppliers of "green technologies", universities and so on,
- participation in work groups of professional associations,
- introduction of environmental management systems,
- the number of "new" water treatment technologies in use (indicating the speed of their diffusion) and
- (changes of) parameters describing the quality of cleaned water.

The indicators are just a few examples for indicators of innovation. A more systematic discussion of different types of indicators is subject of the following chapter.

3 Indicators for sustainable innovation

3.1 Indicator concept outline: multi-level analysis of the impacts of external drivers on innovation for sustainable development

This chapter defines a special indicator system to assess:

1. the impact of innovation drivers on the behaviour of actors (development and dissemination of innovations in the field of water supply and sewage management) (question 1 in figure 1),
2. the general importance of these drivers for the genesis and diffusion of innovations (question 2 in figure 1)
3. the possible impact of these innovations on sustainable development (question 3 in figure 1),
4. the status of sustainability indicators in the water services innovation system (WSIS) (question 4 in figure 1),
5. the factors that determine the dissemination of new technologies (complexity, compatibility, risk etc.) (question 5 in figure 1)
6. the general importance of these factors hindering the use of new technologies or organisational innovations (question 6 in figure 1).

The aspects number 3 and 5 are supplemented by additional evaluation tools to go into more detail concerning the leverage effects of each innovation issue and the diffusion criteria of innovations (see chapter 3.3 and 3.5).

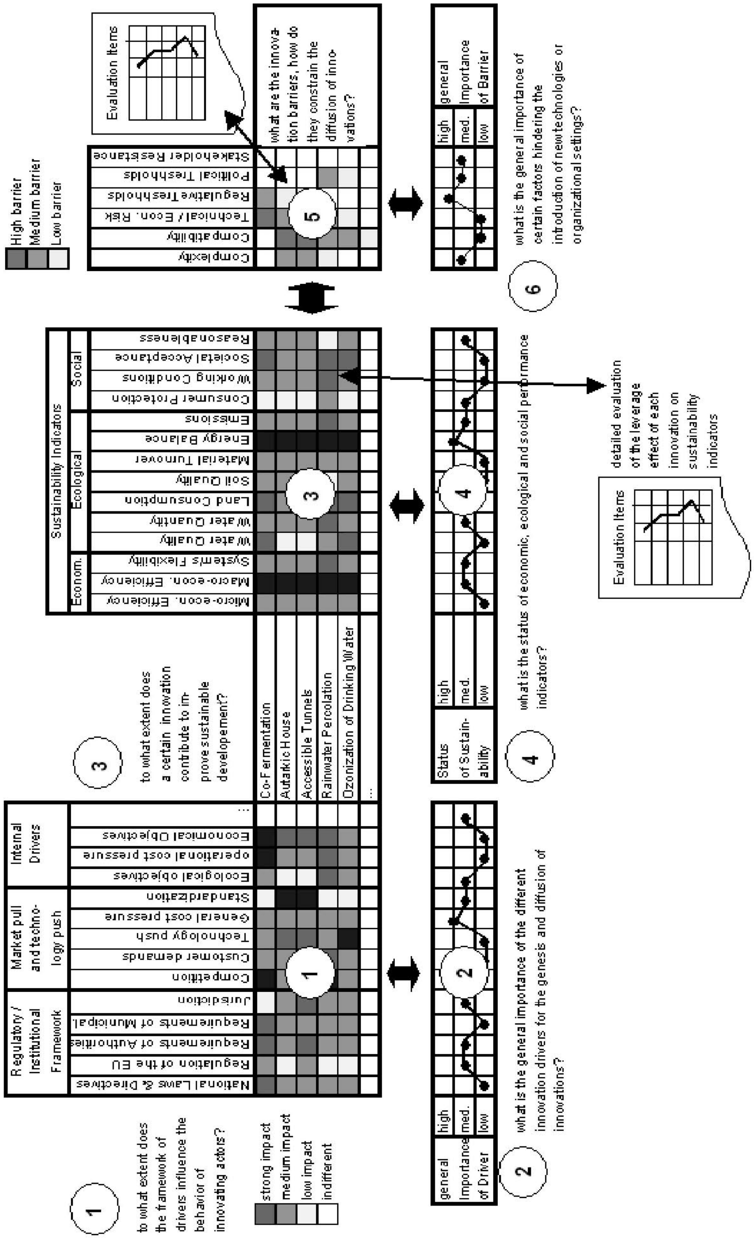


Fig. 1. Proposed Indicator System

The proposed system was developed primarily for the development of hypothesises for the AquaSus project. Secondly, the indicator system may serve as a corporate tool for decision making, since it is of utmost interest for water management companies to guess impacts on their incentive systems and to reach a clear understanding of further impacts of innovations on their business as well as on their economic, ecological and social performance indicators. Thirdly, the indicator system may be used by policy makers in environmental issues.

3.2 Impact of innovation drivers on the development and dissemination of innovations

Based on expert interviews different innovation drivers affecting the WSIS were identified. The elements of the regulatory framework, such as national laws and directives (i.e. the German Federal Water Act, Drinking Water Ordinance), municipal laws, waste laws on federal and municipal level, tax laws are supposed to have a strong influence on innovation behaviour. On the European level regulations such as the IPPC directive[7], the Water Framework Directive, laws governing material flows, bans of certain materials like phosphates, laws for plant protection, have to be taken into account. On the implementation level, requirements of authorities within the approvals of water management systems as well as requirements of the municipalities are also expected to influence the genesis and diffusion of innovations. Even the jurisdiction is supposed to influence the development of innovations, since it prescribes selective behavioural standards for innovation actors, i.e. in the adoption or implementation of technical measures.

Besides regulatory drivers, innovation is triggered by market factors and technology push phenomena. Especially on an international level, German water management companies are less competitive suffering from their fragmented structure compared to e.g. French companies like Suez Ondeo and Vivendi (Deutsche Bank Research 2000). Customer demands (demands for a certain water quality etc.) are expected to gain more importance in the future assuming that especially industry will ask for different water qualities for their processes. Pressures on municipal state budgets as the result of tax shortfalls etc. might force innovation on the supply side. Turning to technology, the availability of certain new technologies may also have an substantial impact on the implementation of new services and

[7] IPPC Council Directive on Integrated Pollution Prevention and Control (96/61/EC) of September 24, 1996

management systems. Lastly, standardisation and institutional arrangements of norm-setting professional organisations affect innovation behaviour: a faster dissemination of new products and services can be expected when they comply with international standards (like ISO, PAS, EMAS, IPPC)[8].

Of course there are additional internal innovation drivers following the idea of a resource-based view and institutional perspectives of a firm as a result of intrinsic incentive systems such as intangible assets, internal sources, development needs of employees. Among these internal drivers ecological objectives (intrinsic ecological objectives as a result of image marketing etc.) may play an important role in the genesis of innovations, as well as pressure on running costs (demand to lower running costs after drinking water and sewage water prices have risen). Finally, economic objectives, e.g. being profitable, drive innovation to a substantial amount, at least in "normal" industries. These drivers may have an impact on certain innovations directly and selectively or indirectly in conjunction with other drivers in the innovation system. So there is empirical evidence of only those regulatory drivers having a serious steering effect on innovation behaviour (for instance the nitrogen legislation) which have their operational execution controlled by public authorities.

The drivers for innovation may be evaluated first according to their general importance on the innovation process by rating their general impact with "high", "medium" or "low". In chapter 4.2. we will give some empirical findings on these evaluations.

Moreover, within the indicator system, these drivers may be evaluated separately regarding their impacts on the development and diffusion of specific innovations (see chapter 3.3). The evaluation procedure uses the following categories of scores for each driver and each technology or innovation:

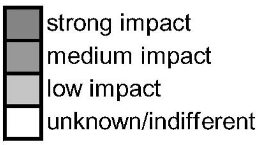


Fig. 2. Strength of impacts

At this point it should be noticed that innovation barriers are treated separately in the indicator system. Thus we differentiate impacts from

[8] ISO: International Standardization Organization; PAS: Publicly Available Specifications; EMAS: Eco-Management and Audit-Schemes; IPPC: Integrated Pollution Prevention and Control

drivers, whether they reveal with positive[9] or negative[10] incentives (related to question 1 of figure 1) or they reveal with innovation barriers, understood as a definite constraint for innovations (question 5 of figure 1).

These informations served as a basis for the items to be tackled in empirical investigations in AquaSus. The hypothesises were included in the questionnaires in form of special questions on innovation drivers (for results see chapter 4.2).

3.3 Impact of technologies on sustainable development

The next step within the AquaSus project was to develop a tool to assess the contribution of an innovation in the WSIS to sustainable development. Referring to question 3 of figure 1, the evaluation in this part of the indicator system follows again a simple process of estimating the leverage effects of each innovation or technology to the sustainability indicators. The scores are the same as in step 1 (see chapter 3.2).

In order to develop an easy-to-understand evaluation process, a tailor-made evaluation scale was developed for each sustainability indicator. These scales (see figure 3) may be called "qualitative scales", since they are non-metric scales, asking the innovation actors for a vote based on their understanding of the evaluation issue, for example specific norms. However, for the specification of these indicators especially in the WSIS and for the purpose of evaluating their sustainability effects, measurable indicators for water extraction and use, quality of resources and drinking water etc. exist. Nevertheless, it should be mentioned that for the specification of an indicator, there is no 1:1 relation between indicator and measurable ratio. On the contrary, different ratios and non-metric scales are often used depending on the kind and scope of the socio-economic empirical study. The indicators and their specific scales for the evaluation process are depicted in figure 3[11]:

[9] For instance a threshold for particular substances determining the water quality

[10] For instance a prohibition by law directing the innovation actor to search for other solutions

[11] Several of these indicators are also part of the indicator system of the Commission on Sustainble Development (CSD), cf. BMU 2000

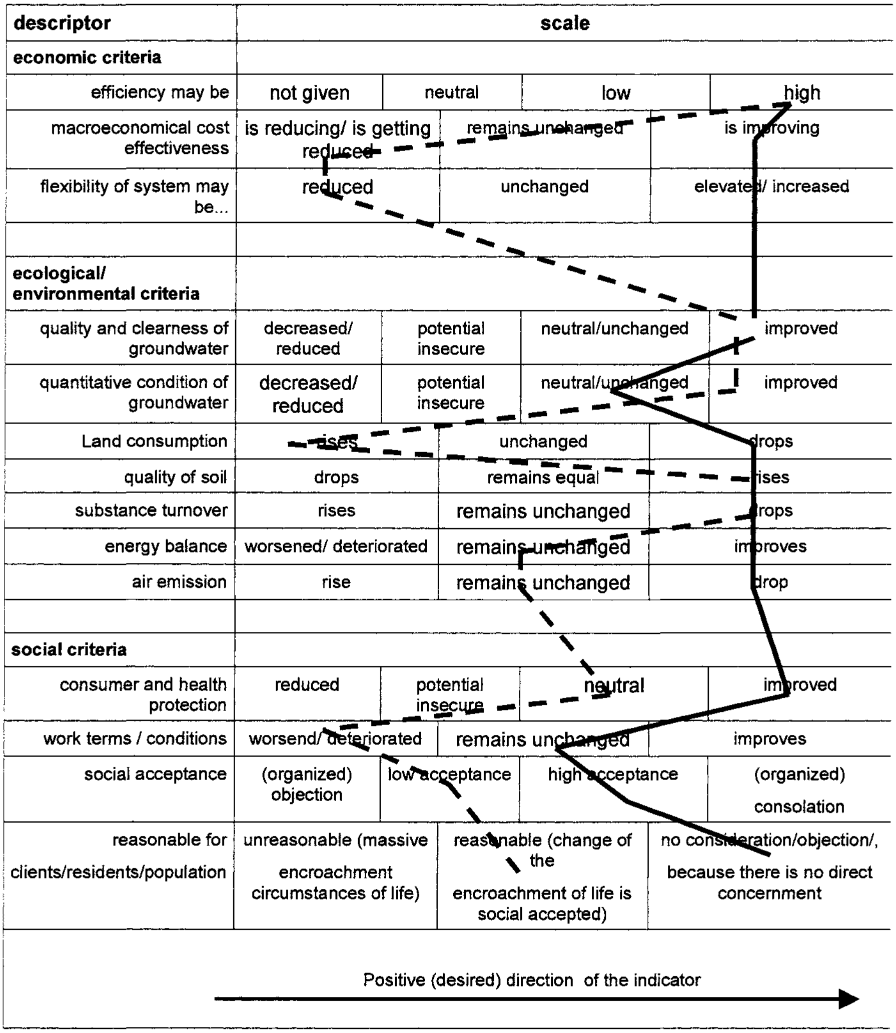


Fig. 3. Scales of sustainability indicators for AquaSus (comprising of two innovations for "Autarkic House" (broken line) and Co-Fermentation (direct line)

3.4 Status of sustainability indicators in the water services innovation system

The indicator system also helps to evaluate the status of sustainability indicators on a normative basis. Since the evaluation step in chapter 3.3 is concentrated on the leverage effect of single technologies or innovations on sustainability (question 3 of figure 1), the evaluation step according to question 4 in figure 1 is directed towards a general assessment of the sustainability indicators in the WSIS. This extension of the system is especially useful for investigations into the innovation system thinking of macro-economic modelling of sustainability indicators.

Even for corporate and political decision processes, the innovation actors may gain a more detailed view about sustainability when using a non-metric scale like "low-medium-high" as used in the AquaSus indicator system. These assessment may be based on normative borderlines like

- limiting values for hazardous substances in sewage discharges,
- average values for efficiency ratios both on macro- as on micro-economic levels, defining the average as "medium score",
- average values for land consumption, material turnover, air emissions and so on.

This – by the way – may be one of the major problems in evaluating the sustainability of a certain innovation, technology or even an entire innovation system: for all of these indicators absolute values may be developed based on primary or secondary statistics, measurements or other data sources. So the ratio "material turnover" might display a value of 200 m^3/inhabitant for instance for sewage sludge, but whether this should be judged as high, medium or low compared to a normative standard is not automatically answered. Within the empirical investigations only "relative evaluations" were undertaken to assess the contribution of certain innovations or technologies towards an improvement of the sustainability indicators. We followed the idea that – based on the principles of sustainability – an unmistakable "positive" and "desired direction" of the values of a specific indicator may be defined (see again figure 3).

However, looking at the indicator system in figure 1, for corporate and political decision makers, this might – as mentioned before – give hints for developing strategies on improving the sustainability of the WSIS as well. To keep it simple: just observe the potentials of the technologies rated at the heart of the indicator system (question 3 of figure 1) according to their supposed leverage effects on sustainability, and compare this with the choice for the status of a certain sustainability indicator. You may find those technologies or innovations which contribute very strongly on this single sustainability indicator by analysing the scores in the rows and columns of the matrix. Of course, this does not assure a "balance" in the development towards sustainability, because a single innovation or technology may contribute positively to ecological objectives but not to social or economic objectives.

3.5 Diffusion criteria of new technologies: innovation barriers analysed

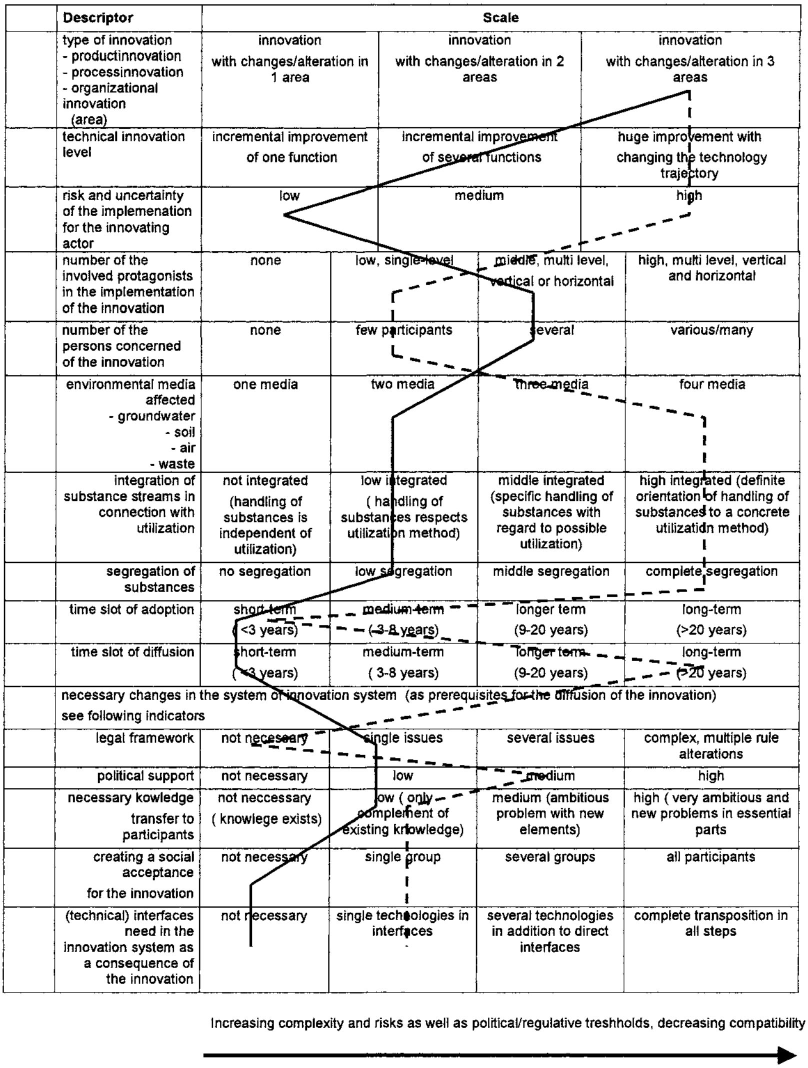
Finally, the impact of an innovation depends on the scope and pace of its dissemination. With this background and looking on question 5 and 6 of figure 1, the next evaluation steps within the indicator system were to set up a tool to assess the diffusion criteria and innovation barriers for the innovations and technologies investigated in the AquaSus project.

The structure of these diffusion criteria rely on earlier works by Rogers and Schoemaker (1971) and Rogers (2003) defining the "diffusion" of an innovation as the process by which an innovation is communicated over time among members of a social system. According to these works the key indicators to explain the diffusion of an innovation are described as follows:

- relative advantage (degree to which an innovation is perceived as being better than the idea it supersedes)
- compatibility (degree to which an innovation is perceived as being consistent with existing values, past experiences and needs of the potential adopters)
- complexity (degree to which an innovation is perceived as difficult to understand and use)
- trialability (degree to which an innovation may be experimented with on a limited basis) and
- oberservability (degree to which the results of an innovation are visible to others).

In AquaSus a special adaptation method of these diffusion indicators was developed to cope with the tasks of the project. Following figure 1 the key questions to be answered were: What are the innovation barriers in the WSIS and how do they constrain the development and diffusion of innovations?

The question regarding the impact of selective diffusion criteria on single new technologies was specified with different indicators following the basic structure of the Rogers-Diffusion-Indicators, depicted in figure 4:



Descriptor	Scale			
type of innovation - productinnovation - processinnovation - organizational innovation (area)	innovation with changes/alteration in 1 area	innovation with changes/alteration in 2 areas	innovation with changes/alteration in 3 areas	
technical innovation level	incremental improvement of one function	incremental improvement of several functions	huge improvement with changing the technology trajectory	
risk and uncertainty of the implemenation for the innovating actor	low	medium	high	
number of the involved protagonists in the implementation of the innovation	none	low, single-level	middle, multi level, vertical or horizontal	high, multi level, vertical and horizontal
number of the persons concerned of the innovation	none	few participants	several	various/many
environmental media affected - groundwater - soil - air - waste	one media	two media	three media	four media
integration of substance streams in connection with utilization	not integrated (handling of substances is independent of utilization)	low integrated (handling of substances respects utilization method)	middle integrated (specific handling of substances with regard to possible utilization)	high integrated (definite orientation of handling of substances to a concrete utilization method)
segregation of substances	no segregation	low segregation	middle segregation	complete segregation
time slot of adoption	short-term (<3 years)	medium-term (3-8 years)	longer term (9-20 years)	long-term (>20 years)
time slot of diffusion	short-term (<3 years)	medium-term (3-8 years)	longer term (9-20 years)	long-term (>20 years)
necessary changes in the system of innovation system (as prerequisites for the diffusion of the innovation) see following indicators				
legal framework	not necessary	single issues	several issues	complex, multiple rule alterations
political support	not necessary	low	medium	high
necessary kowledge transfer to participants	not neccessary (knowlege exists)	low (only complement of existing knowledge)	medium (ambitious problem with new elements)	high (very ambitious and new problems in essential parts
creating a social acceptance for the innovation	not necessary	single group	several groups	all participants
(technical) interfaces need in the innovation system as a consequence of the innovation	not necessary	single technologies in interfaces	several technologies in addition to direct interfaces	complete transposition in all steps

Fig. 4. Diffusion indicators for the Water Services Innovation System (Evaluation example)

According to the indicators displayed in figure 4, the diffusion of innovations in the WSIS is supposed to be more difficult,

- if the type of the innovation touches more than one area/element of the innovation system (i.e. the complexity rises if the innovation comprises both product novelties, process and organisational novelties)
- if the risk of the implementation increases for the innovation actor,
- if the number of innovation actors necessary to implement the innovation increases,
- if the number of environmental media affected increases (i.e. the complexity rises if the innovation touches at the same time groundwater, soil, air and waste questions and regulatory regimes).

These hypothesises were developed prior to the empirical investigations for AquaSus to structure the questionnaires in the areas of water supply and sewage water disposal.

The clusters displayed in figure 4 represent an analysis of diffusion indicators for the innovations

- Co-fermentation (of sewage sluge and biodegradable waste) (direct line)
- Autarkic House (self-sufficient, autonomous house concerning water supply and sewage treatment) (broken line)

based on expert interviews.

In terms of the general impact of diffusion barriers on the innovation process (question 6 of figure 1) some empirical findings will be presented in chapter 4.2.

4 Selected empirical results from the AquaSus project

The conventional notion of the term innovation as it is used for example in OECD (1997) refers especially to firms as innovating actors. Their management and performance depend according to the traditional industrial economics on basic conditions of the market's supply and demand side (e.g. technology, price elasticity, substitutes) and its structure (e.g. number of firms and customers, entry barriers, cost structures) (Scherer 1970). These issues are not only the outcome of market processes but result in many cases directly from the institutional environment that firms are embedded in. The national innovation system (NIS) approach takes the effects of institutions on innovations explicitly into consideration (Nelson 1993; Lundvall 1988, 1993). Furthermore, it is stressed that firms normally collaborate when innovating instead of undertaking all innovation activities within their hierarchy (Edquist 1997; OECD 2002).

With this in mind, we will briefly discuss the most important institutions, basic conditions and the market structure of the German waste water sector in the following chapter. After that the actual impact of single factors will be discussed (chapter 4.2).

4.1 The waste water services innovation system: market structure and regulatory framework

According to the German constitution (Art. 28 II Grundgesetz) waste water management is a sovereign task of the municipalities. They can decide between running on their own a waste water firm and delegating the task to independent service providers. However, they retain the ultimate responsibility which means they need to supervise the agent (Boscheck 2002). Only recently some few Federal States (Länder) allowed an assignment of the duty itself to private firms. Thus, Germany's market for waste water services is fragmented into many small "disposal areas" which are protected from competition by legal barriers to entry. These result from the fact that waste water services are classified by law as a sovereign task and that municipalities can force their residents to be connected to the public sewerage system and to enter into contract with the public firm ("Anschluss- und Benutzungszwang"). Thus, the municipalities play an important role within the innovation system (Clausen and Rothgang 2004).

While the markets are normally congruent with the administration districts, they can also consist of several municipalities that carry out waste water services in a common firm. Nevertheless, direct competition between firms, which is an important driving force for innovations, does not exist. Because of this and of certain rules for firms under public law, indicators like low prices, high profits or even the mere survival of a firm are not available to discuss the innovative behaviour of waste water firms. Anyway, those indicators would have only limited informative value unless external effects – the environmental benefit or damage of an innovation – are not fully internalised.

About 93 percent of the population are connected to the public sewerage network so that in Germany collecting waste water is a network-based industry (Statistisches Bundesamt 2001). The network generates about two third of the total costs of the disposal of sewage. This means that drain off waste water is not only characterised by legal but also by economic barriers of entry. These arise because pipe networks are accompanied by sunk costs, i.e. investment in pipes is neither recoverable nor can be used for other purposes (ENGREF et al. 2003). Sunk costs cause path dependencies and lock-in effects with regard to innovations (see Sartorius in this volume). As long as investments are not fully depreciated, a switch to another technology is more difficult than without sunk costs. How important this innovation barrier is in the individual case depends on the type (durability) and state of a certain part of a network and also on any facilities like sewage treatment plants that are complementary to a sewerage system.

The environmental regulation of the sector is dominated by command-and-control instruments even though taxes are levied on water abstraction and waste water discharges. In principle, all water uses require an official permission or a licence (§ 2 WHG). A permission to discharge waste water into rivers and lakes requires that harmful substances will be kept down as low as it is possible with water treatment techniques satisfying the "state of the art" (Stand der Technik). Before the WHG-amendment of 1996 only "generally recognised rules of technology" (allgemein anerkannte Regeln der Technik) were prescribed. The definition of uniform technological specifications takes place by close co-operation between representatives of water utilities, professional associations and the water authorities (BMU and UBA 2001).

However, against the background of the current regulations and the economic characteristics of the assets we can assume that the firms for the greater part of innovative activities stick to the well-tried technological trajectory. Though it is questionable whether a network based system remains flexible enough to deal with a declining water demand and the decrease in population in the long term. These developments might increase the pressure to innovate more radically. But the economic barriers to entry will not shrink until substitutes like small, decentralised cleaning systems are available with lower average costs than the current waste water fee. A prerequisite for the dissemination of those technologies is, on the other hand, that the legal entry barriers will be abolished.

4.2 Determinants of innovation

Finally we will present some results of a survey conducted among nearly 700 German waste water firms which are members of the "German Association for Water, Waste Water and Waste Services"[12]. We confined the analysis to three of the aspects introduced in chapter 3:

- the impact of factors belonging to the framework and market conditions on innovation,
- the role of the municipalities with regard to innovation,
- co-fermentation as an example of an innovation.

[12] Cf. Clausen et al. (2003) for a comprehensive description of the results

Asking the firms for their subjective perception of the importance of different innovation drivers, it turned out that the factor "cost pressure" is presently the most important driver from the firms point of view[13]. Almost 90 % of the firms which answered rate the total cost as 'very significant' or 'significant' for their innovation activities. Running costs are noticed to have a significant lower but nevertheless a high importance for innovation (position 4). Demands of authorities are judged as almost of the same importance as national acts and ordinances (position 2 and 3). Compared with these four factors, customer demands and competition play a minor role as innovation driver, they are placed at position 12 and 14. This is not surprising since direct competition, e.g. a choice between different suppliers, is missing. Thus, innovations are not particularly driven by the demand side of the market. Compared with these factors technology push is a bit more important: about every other firm judged the availability of new technologies as a very significant or significant driver (position 11). All in all especially costs aspects and the factors of the regulatory/institutional framework of the WSIS motivate firms to innovate. In future, regulation on the European level are supposed to have the biggest impact on innovation processes in the WSIS (58 of 261 answers) followed by "general cost pressure" (30 of 261), "running costs" as well as "national laws and ordinances" (both 25 of 261), "competition" (24 of 261) and "ecological objectives" (20 of 261). Among the future drivers "requirements of municipalities, "norm-setting authorities" are ranking low with 3 and 7 of 261 answers respectively.

Asking the firms to evaluate the importance of innovation barriers, it turned out that the cost aspect is regarded as the most important factor. The influence of some factors depends apparently on the kind of innovation. The same applies to the influence of the municipality on firms' innovation activities. On the one hand about 55 % of the firms have answered that demands of local politics do motivate their innovation activities (position 9). At the same time about 34 % of the firms take the view that the introduction of new technologies or organisational changes is hindered by local politics (position 2). Every fourth firm blames the local law for hampering innovations (position 3)[14]. A cost-cutting innovation might be promoted more likely by the municipality as an innovation that "solely" improves the quality of treated waste water.

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[13] The factors were put in order by using the Wilcoxon Matched-Pairs Signed-Ranks Test

[14] Unfortunately the answer items of both question (motivation - obstacle) were not exactly the same and so the assessment of the overall effect of "local factors" is a bit difficult

The manner in which a municipality may hinder innovation activities can be illustrated by examples the firms mentioned in the survey. Several expressed that members of the municipal council were not willing to give up influence and are inclined to make decisions according to political reasons. Two firms stated that they could not introduce fee systems that realise the polluter pays principle better than the united fee for rainfall water and for waste water. Other firms criticised that their municipal council makes investment decisions conditional on initial set up costs while neglecting to look at long-term advantages and running costs.

Altogether, it seems possible to identify general determinants of innovation in the WSIS. However, direction and strength of the influence of a factor have to be judged for concrete innovations. Regarding co-fermentation it turned out that the expenditures necessary to introduce this treatment process for sewage sludge and the biological waste procedure are judged only by 17 % of the firms as "too high"[15]. Even though the technology does exist already for some years, nearly every third firm does not know about it. Besides, many firms believe that the technology has no advantages (23 %) compared to other methods and that it is accompanied by problems with the process technology (22 %).

5 Conclusion

The evaluation process within the AquaSus project shows, that – based on expert interviews prior to the empirical investigation – the concept of the indicator system can be used successfully to structure the discussion on the impacts of innovation drivers in the WSIS. Although not all of the elements of the indicator system were used in AquaSus, the system of interrelationships between innovation drivers, innovations, diffusion criteria and sustainability indicators shown in figure 1 contributed extensively to the process of formulating the hypothesises in AquaSus.

To conclude, a core set of substantial hypothesises can be derived from the experts′ votes for clustering the innovations according to figure 4 and the empirical investigation presented in chapter 4.2:

Thesis 1: The most complex innovations do not necessarily contribute to a greater extent to sustainable development in the WSIS than less complex innovations do.

Thesis 2: Even if the micro- and macro-economic efficiency of water management innovations is assured, the diffusion of the technology is not

[15] Nisipeanu and Thomzik (2004) explain the characteristics of co-fermentation and discuss any legal problems that may hamper the wide use of this process

necessarily assured, because the decision processes at the firm or municipal level might not be rational.

Thesis 3: According to thesis 2, a crucial innovation barrier might be the criteria of municipal decision making (investment costs instead average costs) as well as the conjunction with electoral cycles (increasing fees for water supply, sewage water disposal or waste management are unpopular).

From these findings we learned that our preliminary hypothesis has at least to be questioned: starting AquaSus with the general assumption that a quantum leap in sustainability may only be reached if comprehensive system innovations can be implemented, i.e. with the introduction of new integrated water service and sewerage systems that

- involve all actors in the innovation system,
- comprise product-, process and organisational change,
- lead to a new technological trajectory,
- integrate substance streams with a high orientation towards utilisation,
- reach a high segregation of substances,
- need alterations in the legal framework,
- has to create social acceptance in all parts of society.

The exploration of the in-depth clusters of technologies using the indicators of figure 1 (especially referring to questions 3 and 5) lead to a different result as stated in thesis 1-3.

However, coming back to methodological problems of the use of the indicator system, in our opinion the need of a comprehensive indicator system is obvious in order to assess contributions of innovations to sustainability. The examples investigated in AquaSus demonstrate that we will not be able to find a single indicator of sustainable innovations. As shown in chapter 1 and 2, the vision of sustainable development is rather complex. Since the environment of waste water firms in different regions may be different, not necessarily regarding the regulatory/institutional framework but with respect to the environmental/resource problems and the situation within the firm (organisational arrangement, culture), a comparison of patterns might help to reveal the main drivers of those innovations with predominantly positive contributions to indicators of sustainability. For these applications the indicator system may give a guidance for assessing systematically the chain from innovation drivers via incentives for innovations towards their contribution to sustainability. The indicator system presented in this paper may assist corporate decisions on these issues by asking a number of questions in form of indicators to be filled with data and information. In this context we learned that qualitative assessments of the impacts of innovations as made in chapter 3 are – in our view – not necessarily worse than quantitative assessments, even if it is desirable to assess the impacts in a quantitative way wherever possible.

As discussed in chapter 2.1. the details of an indicator system for sustainability are not worked out yet. Although principles of sustainable water management exist as indicated in table 1 and single indicators have been set up, so far we do not know the relationship between these indicators. The indicator system may help to agree on indicators of sustainability and on the values indicating the "Guard Rail", i.e. where to move without causing unreasonable environmental and sustainable impacts.

Hence, definitions and target values have to be defined on different levels (national, regional and local authorities). Mutual starting point for all actors in the WSIS is the legal framework. However that does not take everything into account. Waste water management firms – as a normative requirement – need to direct their innovation actions to those measures contributing to sustainability. Since the objectives given by the legal framework may be fragmented as the result of different legal regimes and overlapping ordinances, the targets so far may be too narrow and do not provide these 'Guard Rails' to sustainability. The indicator system presented in this paper may widen the scope of objectives by introducing driving, state and response indicators going beyond the medium water and asking for a transmedia-impact analysis of innovation measures in the WSIS.

Lastly, the indicator system may assist in setting up benchmarks between different companies or municipalities according to their innovation performance towards sustainability. Further research may be concentrated on the use of the indicator scheme in practise in order to reveal the patterns of successful innovations contributing to sustainability. These analyses should be conducted with the help of econometric methods based on survey data following the questions in the indicator system. The results of these investigations may acknowledge the so far qualitatively assumed leverage effects of water services innovations towards sustainability.

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