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Sustainable Urban Water Management in Germany

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Evaluation of micro-transitions and discussion of their upscaling

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ABSTRACT

Water is at the core of human existence. It sustains life in all its facets. Therefore, it is of vital importance to ensure a long-term and reliable supply of water. Achieving such supply implies a careful and considerate management of water. Human beings have an impact on water condition in both quality and quantity and are at the same time dependent on good water conditions. An opportune arena representing the relationship and interface between human existence and water is the urban area as it reveals the interruption of the natural water cycle: A city symbolizes the abstraction of water and the discharge of used water as well as the decreased infiltration and evaporation due to sealed surfaces. As such arena, a city also contains an enormous potential for improving the mutual relation of water and human civilisation. An approach addressing this relation is Sustainable Urban Water Management (SUWM). In Germany, pilot-projects implementing SUWM exist. Five of such pilot-projects are compared to meet the aim of this thesis, which is finding impeding and supporting conditions to the implementation of SUWM and discuss the role of SUWM in Germany. Lacking cost-efficiency and institutional inertia have been found as main obstacles and individual persons supporting the project and frequent communication addressing prevailing uncertainties as main support. Drawing on transition theory, SUWM in Germany has been placed in the beginning of a transition from the traditional urban water management to a novel urban water management not necessarily consisting only of SUWM but acknowledging SUWM as an opportune approach. It is suggested to policy and planning practice to seize SUWM as a feasible alternative to the traditional urban water management and make it a requirement for planners to assess its implementation when developing an area.

Key-words: Sustainable Urban Water Management, Micro-Transitions, Upscaling, Climate Change Adaptation, Environmental Sustainability

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ABBREVIATIONS AND TERM DEFINITIONS

EEA	European Environment Agency
EU	European Union
HWC	HAMBURG WATER Cycle
IGB	Fraunhofer Institute for Interfacial Engineering and Biotechnology, Stuttgart
ISOE	Institute for Socio-Ecological Research
SUWM	Sustainable Urban Water Management
UN	United Nations

Blackwater	Heavily polluted wastewater from toilets
Greywater	Slightly polluted wastewater from the kitchen and bathroom
Rainwater	Any precipitation; includes stormwater
Existing structure	Describes the existing housings and water infrastructures (such as pipes)

1. The Significance of Urban Water Management

In this chapter, the thesis is embedded in its thematic background, giving insight on the importance of urban water management and introducing Sustainable Urban Water Management (SUWM). The societal and academic relevance of this research is explained and the research questions are presented.

1.1. The Delicate Matter of Water and its Management

Water is at the core of human existence. It is not only a vital resource for any kind of life on Earth but also regarded as human right (Jackson et al., 2016). Water sustains human`s prosperity. Settlements have arisen and developed on the shore of water bodies (Grimm et al., 2008). Over time and with its usage, water sources degenerated; they were polluted and depleted (Jackson et al., 2016). Adversely to this development is the trend of future population growth which means an intensified pressure on water bodies (Harper, 2013). Likewise, economic growth signifies an increase in water demand (Jackson et al., 2016). In the past, water use has even been growing faster than population growth (Lazarova and Asano, 2013). The 'Blue Planet' is covered with water but only a minor part of this, 0,001% of the total water amount, is usable for human`s freshwater needs (Lazarova and Asano, 2013). This gives an idea of the difficulties of water scarcity that humans will and already are encountering and describes the need to value water and handle and manage it carefully. The term 'water scarcity' describes not only water shortage but likewise its deterioration and competition for it (Lazarova and Asano, 2013).

According to the European Environment Agency (EEA, 2016) water stress is not uncommon within the EU. This mostly concerns Mediterranean countries where some regions even face a permanently stressed situation. Water stress is defined by the EEA (n.y.) as the stage where demand for water outpaces its availability either due to low quantity or due to poor quality, which makes it narrower than the term water scarcity. Water stress is not only the result of but can also cause quantitative (e.g. overexploitation) and qualitative (e.g. eutrophication) degradation. In summer, with dry conditions, around 14% of the population of the EU have to deal with water stress conditions (EC, 2012). At this time of the year, water stress is not only an issue in the Mediterranean but also in Northern European countries such as the UK or Germany (EC, 2012). The EC (2012) expects an increase of river basins affected by water

stress in summer by up to 50% until 2030. Therefore, it is substantial to be concerned with water bodies` water quality and quantity.

In the EU, the Water Framework Directive is in place to improve the overall conditions of water bodies (both surface and groundwater). Improvements have happened, but the current status of water bodies is still not satisfying (EEA, 2015). The status is benchmarked to a water system with low human impact and measured on basis of standards set for river morphology, ecology, chemistry and quantity (EEA, 2015). For example, the species composition or degree of alteration of the hydromorphology are indicators to assess a surface water body`s status. A good ecological status is reached when the indicators 'show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions' (EC, 2000, p.38). Concerning groundwater, it is distinguished between quantitative and chemical status: A good quantitative status is achieved when 'the long-term annual average rate of abstraction' does not exceed the available resource (EC, 2000, p.60). A good chemical status is reached when pollutants do not exceed set standards and when there is no saline intrusion (EC, 2000). Thus, both qualitative and quantitative parameters are of importance for assessing the status of a water body. Figure 1 shows a classification of the ecological status of water bodies in the EU.

Urban areas are partly responsible for pollution of surface waters, e.g. through sewage overflow or insufficient treatment, and additionally contribute to over-abstraction of both surface and groundwater bodies. Other responsible factors are inter alia agriculture and industrial activity (EC, 2015).

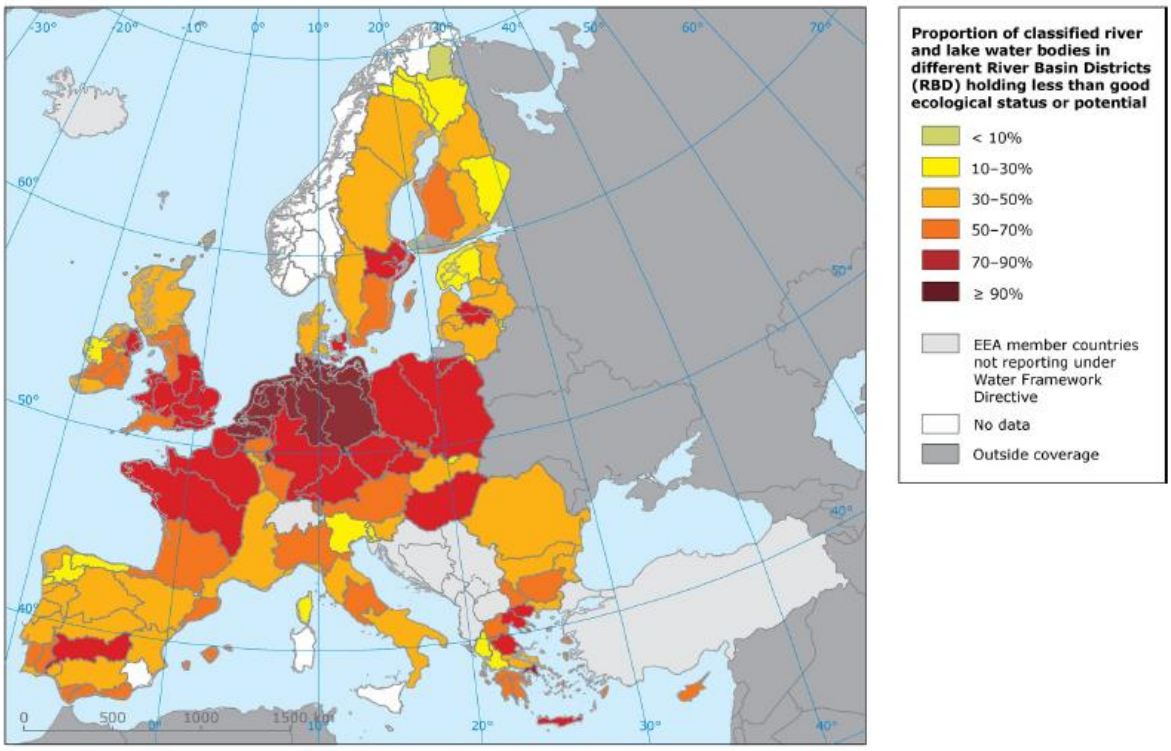

Figure 1: Illustration of the ecological status or potential of rivers and lakes within the EU (EEA, 2015).

Water and its management delineate a key factor that can contribute to urban sustainability (Marlow et al., 2015) as urban areas not only contribute to pollution and overuse of water bodies but also disrupt the natural cycle-like pathway of water (Hoyer et al., 2011).
The intervention, usage and discharge, in this cycle disrupts the natural flow of precipitation, infiltration and evaporation (Hoyer et al., 2011). Compare Figure 2 and 3 for an impression.

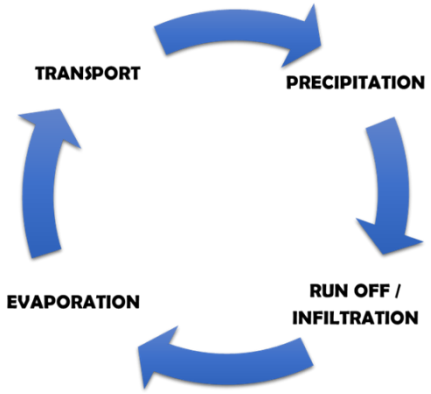

Figure 2: Natural water cycle (modified after NASA, n.y.).

Management of water is needed for coordinating, facilitating and enabling the use of water in its diverse forms which can be industrial or commercial, domestic or for more natural purposes as e.g. irrigation (see Figure 3 and 4, both showing elements of management). Likewise, the handling of the used water and rainwater needs to be regulated to reduce

potential risks in terms of flood hazards or health issues (Daigger, 2011). Cities, as an agglomeration of people, represent a major demand for water, as well as a considerable source of discharge of wastewater (Grimm et al., 2008). Although cities are often located on natural water bodies, these local water resources usually cannot provide sufficient water to the large urban centres. Instead, cities, in Germany defined by a minimum of inhabitants of 5.000 and the function of being a centrum (BBSR, 2014), are usually fed by surrounding water resources (Mull et al., 2002; Birkenholtz, 2016) and thus have an impact on the status of these surrounding water bodies.

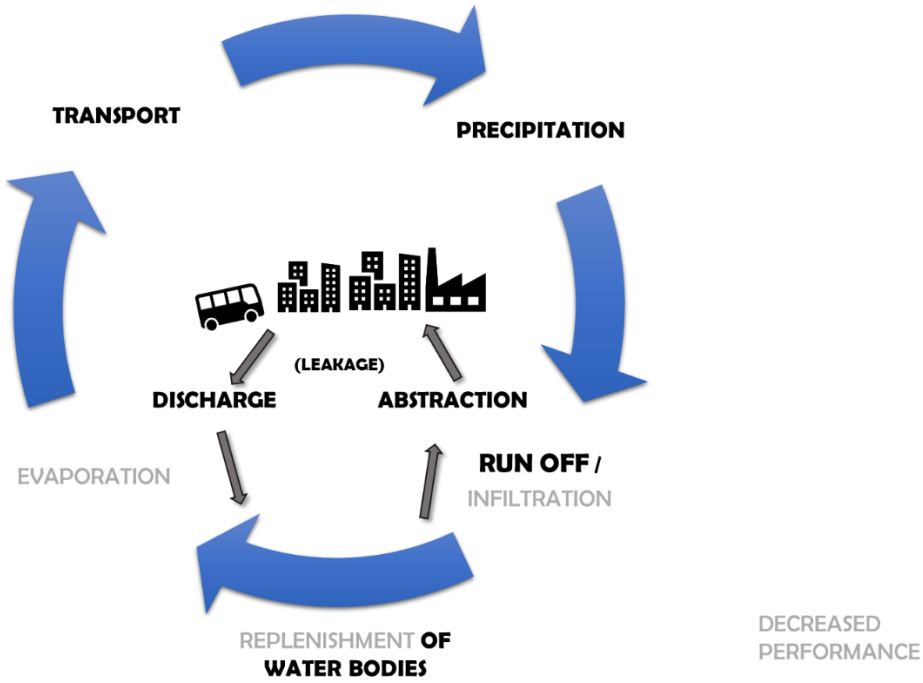

Figure 3: Urban water cycle (modified after Marsalek et al., 2006; NASA, n.y.; Ott et al., 2016).

The demanding use and discharge of water displays that a city is an arena of interaction of human beings and natural environment. The reciprocal relationship between an urban area and the freshwater system is pointed out by the UN describing the city`s dependency on freshwater and its enormous impact on freshwater systems (UNW-DPAC, 2010). The pollution and overexploitation of water is opposing the long-term need of providing water as a basic human right that is also required to pursue the fulfilling of other human rights (Birkenholtz, 2016; Jackson et al., 2016). A city, determining the connection between people and nature, has an impact on environmental sustainability (Naumann and Bernt, 2009).

Traditional urban water management is based on a linear structure that abstracts water from regional aquifers or rivers, delivers this water to the city where it is used, whereupon the generated wastewater is discharged back into the natural water system (Marlow et al., 2013;

Werbeloff and Brown, 2011). There is no consideration of the natural water cycle with evaporation and precipitation. The system is of a one-way direction and very linear (see Figure 4 as an example for this linear water system and Figure 5 for the disturbed water cycle with regard to stormwater management). Daigger (2009) refers to this as the '*take, make, waste* approach' (p.809, italics in the original). The installed water infrastructure system, consisting of sewage, pipelines and water and sewage treatment works has not been put into place all at once but the different functions were implemented step by step throughout centuries (Marlow et al., 2013). As Gandy (2004) describes, the evolution of a centralized water system containing water supply and sewage started in the 19th century. This emergence is ascribed to follow an interaction between technology and humans and reveals the close relationship between nature and culture (Gandy, 2004).

Considering the above described importance of circumstances of water shortage and contamination of water, it is questionable whether this linear approach is suitable for dealing with water in the long term.

Figure 4: Traditional and linear approach to urban water management (modified after Ott et al., 2016).

Next to water shortage and contamination, a further challenge to the current water management is represented by urbanization. With a growing number of people and houses that need to be included in the water management the currently implemented system is challenged to adapt to these changes (Grimm et al., 2008). The other way around water itself represents a challenge to water management as cities are highly vulnerable to flood because of the largely sealed surface (Gondhalekar and Ramsauer, 2017). The existing stormwater management facilities cannot adapt to changing conditions through climate change or a growing city (Hoyer et al., 2011).

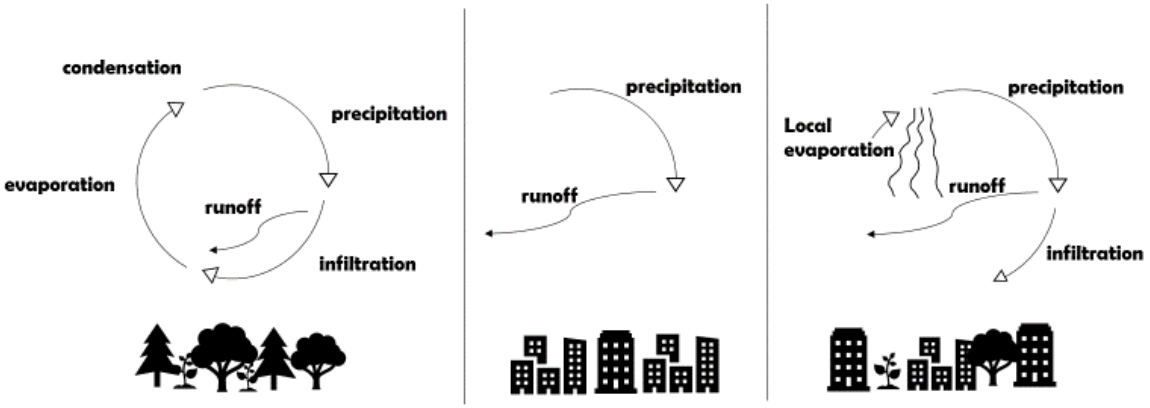

Figure 5: A natural water cycle (left, a city-disturbed water cycle (middle) and a city with sustainable stormwater management (modified after Hoyer et al., 2011).

Furthermore, climate change is exacerbating the problem of water stress. Volatility in climatic conditions such as change in temperatures, length of dry seasons or pattern of precipitation will lead to an altered water resource distribution (Lazarova and Asano, 2013).

Ott et al. (2016) state that the challenges for the German urban water management are demographic change, increasing energy prices and climate change which altogether exert a pressure for change.

The described impact of urban areas on the water system and the explained challenges of urbanization and climate change underline the deficits of the current urban water management and enforce the need for a form of urban water management that can deal with these challenges.

1.2. SUWM as Upcoming Form of Management – Objectives of this Research and its Relevance to Society, Planning Practice and Theoretical Debates

SUWM is an approach of urban water management that is integrative and adaptive in both management and infrastructure. By incorporating all forms of water (e.g. rainwater and used water), it increases the variability of water sources as well as reduces the efflux of wastewater. In addition, it combines central and decentral infrastructure (see definition Section 2.1.1.).

SUWM is widely discussed as a desirable new water management approach in literature (see for instance Brown and Farrelly, 2009; Brown et al., 2011; Daigger, 2011; Marlow et al., 2013; Belmeziti et al., 2015). However, it is not implemented abundantly in reality (Marlow et al., 2013). To date, only small-scale projects of SUWM exist (Brown et al., 2011). These are for instance greywater treatment and rainwater harvesting in Melbourne (Farrelly and

Brown, 2011) or the processing of wastewater through river bank infiltration in Berlin (Salian and Anton, 2011). Furthermore, when discussing and advocating for an alternative approach to urban water management, often, no practical guidelines are provided by academics promoting such alternative approach (Werbeloff and Brown, 2011). Brown et al. (2011), argue that there is a need for a detailed examination and further research of micro-transitions where a SUWM project or technology has been successfully implemented. This thesis builds on this suggestion and aims at comparing cases of micro-transitions towards SUWM. A further goal is to use this comparison to develop suggestions for an upscaling of SUWM.

Accordingly, the **research objective** of this study is to provide a scheme of the conditions that are important when introducing SUWM in a city and to identify planning and policy implications based on found conditions. It is discussed if an upscaling of SUWM is possible and desirable for the population of Germany. Thereby, SUWM in Germany is linked to transition theory and the examined cases are placed within a supposed transition from the traditional urban water management to a novel urban water management incorporating SUWM. The discovered supporting and impeding conditions are applied to the discussion on upscaling SUWM and can be beneficial for other cities that could use the existing knowledge and create favourable conditions before implementing SUWM.

Relevance of the Research

SUWM aims at responding to the current difficulties and the inability to change to altered conditions that the urban water sector is confronted with (Brown et al., 2011). SUWM is concerned with the impact of urban water management (thus, the abstraction and discharge of water) on the environment and recognizes environmental vulnerability (Belmeziti et al., 2015; Marlow et al., 2015). It takes the natural water system into account and pursues a different governance approach than the traditional water management that is not predominantly based on hierarchy and centrality (Brown et al., 2011). SUWM is regarded as a more appropriate alternative as it makes use of so far unused water sources and reduces the negative impact on the environment and is therefore better suited for meeting possible water scarcity and diminishing an adverse impact on the environment (Wong and Brown, 2008; Werbeloff and Brown, 2011).

Pahl-Wostl (2007a) speaks of the necessity to globally make water management more adaptive for dealing with uncertainties linked to climate change. SUWM could be a contribution to such adaptivity, inter alia because one feature of SUWM is decentralization

(Marlow et al., 2013; Brown et al., 2011). In a decentralized situation, the water system can be adapted to local conditions which provides the opportunity of coupling quality of water to the water use (Sharma et al., 2010). Adaptation furthermore compromises the adjustment to future evolvements due to climate change and on a management level, the inclusion of learning into the management style (Pahl-Wostl, 2007a). For dealing with climate change, it is important to assess SUWM as one option to achieve more adaptability, which would then influence the desirability of an upscaling of SUWM.

The described challenges (e.g. climate change or demographic change) for the water system have an effect on (spatial) planning which would be needed to facilitate the implementation of SUWM in finding suitable places and applications. The linkage of land use and the water system is part of the new understanding of water management (Brown et al., 2011). This research will contribute to a better understanding of the conditions a planner has to be aware of in pursuing an implementation of SUWM and gives concrete suggestions to planning practitioners.

This thesis shows societal relevance as SUWM could allow for a secured future water supply without deviating from ecological sustainability (Brown et al., 2011). Answering the research questions of the thesis (see the following Section 1.3.) contributes to a discussion about the future water management in Germany and to what extent SUWM is a potential next stage or step. The benefits of SUWM and the determining factors to its implementation are evaluated.
Daigger (2009) points out that a change in urban water management is needed as major challenges are faced. These are: Population growth, accompanied by an urbanization; escalated water scarcity due to climate change; the need to diminish the utilization of water as a consequence of the previous challenge. And last, the reduction of pollution of the environment by nutrient discharge. These four aspects indicate that first, the problem is global and almost everyone is or can be affected, and second as already described above, SUWM can potentially be the answer to these challenges as it aims at urban areas, is more flexible to changing conditions, implies a reduced use of water and by the reuse mechanism a decreased nutrient discharge.

1.3. Questions Arising

In this thesis, the empirical research context is set on Germany (see Section 4.1. for a description of the research context). A reduced water availability due to climate change is expected (Hillenbrand et al., 2013). Germany uses ground- and surface water for its water supply and is therefore dependent on a good status of these water bodies now and in future. In Germany, SUWM is an approach already discussed (Green, 2011) and research on the urban water infrastructure is expedited and funded by the German government (NaWaM, n.y.).

In examining the different cases of successful small-scale projects, a comparative research will be conducted to answer the **research questions** of this thesis:

What are the supporting and impeding conditions to an implementation of SUWM in the cities of Germany and what does this imply for a potential transition in urban water management?

- What does SUWM contain in terms of key features or characteristics setting it apart from other forms of urban water management and why are these better?
- What is SUWM`s potential to contribute to a city`s climate change adaptation?
- What are drivers and impediments to the implementation of SUWM as recognized in literature?
- What is a micro-transition in urban water management?
- What are the impeding and supporting conditions to an implementation of SUWM as defined within the research on the cases in Germany?
- What of the found conditions can be transferred to areas with established (water) infrastructure?
- Can the German small-scale SUWM projects be defined as micro-transitions and what is the potential of SUWM for upscaling and evolving into or contributing to an urban water management transition?
- What are the implications of the found impeding and supporting conditions in implementing SUWM for planning practice and policy in order to upscale SUWM and to what degree is an upscaling of SUWM desirable or beneficial?

2. Connecting SUWM to Theoretical Notions – Defining, Discussing, Developing

The purpose of this chapter is to provide a theoretical background, thereby answering the theory-related sub-questions of this research. Additionally, it will draw attention to what to examine in the cases and what conditions to look at. This chapter serves as point of departure for the discussion of the cases and the advice for a larger implementation of SUWM.

A theoretical framework is provided to embed and position this research in current debates not only of SUWM per se but also within other theories and concepts such as transition theory. This leads to a better understanding of SUWM. Relating SUWM to other concepts and theories, thus positioning SUWM within a wider theoretical context, is relevant for a possible generalisation of the results of the case studies (Mjøset, 2006). By linking the cases to a theoretical background, it can be referred to suppositions of other theories. Observations made can be connected to the theoretical framework (Rose, 1991).

First, the term 'Sustainable Urban Water Management' is defined as it is used within this research. This will address the first sub-question of: *What does SUWM contain in terms of key features or characteristics setting it apart from other forms of urban water management and why are these better?* The notions of adaptability, integration and decentralization are given particular importance as they are key components of SUWM. Followingly, it is elaborated on climate change adaptation and its link to SUWM. This will address the second sub-question: *What is SUWM`s potential to contribute to a city`s climate change adaptation?* This is succeeded by a section on the impeding and supporting conditions to the implementation of SUWM. In this section, the third sub-question will be addressed: *What are drivers and impediments to the implementation of SUWM as recognized in literature?* Hereafter, the theoretical concept of transitions with focus on micro-transitions and upscaling is specified to position SUWM in Germany within the process of a transition and discuss the potential upscaling of SUWM. In that, sub-questions four and five will be approached: *What is a micro-transition in urban water management?* and: *Can the German small-scale SUWM projects be defined as micro-transitions and what is the potential of SUWM for upscaling and evolving into or contributing to an urban water management transition?*

2.1. Diving into SUWM

2.1.1. Thorough Definition of SUWM

The notion of SUWM is not defined clearly in scientific literature addressing SUWM. It is explained to be a next step or shift forward in the management of urban water. What exactly this step signifies can have different nuances. These nuances are summarized in Table 1. The authors referred to in this table are the main sources of this section. Often, a comparison to the existing urban water management is made to accentuate SUWM. Based on the conformities between these descriptions, a definition is derived that is used for this thesis.

Aspect	Brown et al. (2011)	Marlow et al. (2013)	Belmeziti et al. (2015)	Daigger (2011)	Brown and Farrelly (2009)	Wilderer (2011)
General Aim (Consideration of water)	Have interrelated water services, deliver most appropriate form (fit-for-purpose uses)	Next step of co-evolution (more benefits), green issues (ecological health, SD), awareness of vulnerability	New services: ecosystem protection, water resource preservation, consider storm and wastewater as resource, not as nuisance	Reuse of used (waste stream as resource), enhance/restore environment, use of local supplies	Non-traditional resources, fit-for-purpose, integrated/adaptive/coordinated/participatory approach, transition/shift	Participatory, reuse measures
Management	Adaptive, integrative, co-management (government, businesses, community), demand management, interdisciplinary, risk sharing among public and private	Integrated	Interaction and cooperation between all stakeholders and institutions involved, integrated	Increase water efficiency, minimize energy use	Manage urban water as total water cycle, demand management and supply	Orientation on recharge rate
Infrastructure	Flexible solutions, wastewater recycling	Decentralised	Integrated, reuse of storm and wastewater	Hybrid system, combine central and decentral	Decentral	Decentral, processing at individual household

Table 1: Summary of the key aspects of SUWM as derived from various authors. The partition into aim, management and infrastructure follows a suggestion by Marlow et al. (2013) (author, 2017).

New and more services or benefits such as ecosystem protection or restoration of the environment are obtained in SUWM. This shows the stronger emphasis on ecological aspects and an awareness of vulnerability of water systems (Marlow et al. 2013). This awareness leads towards the goal of 'managing urban water as a 'total water cycle'' (Brown and Farrelly, 2009, p. 839, quotation marks in the original) in which the natural flow of water is mirrored.

A further feature is to regard additional sources of water as a resource. This can be used water (wastewater), rainwater or stormwater that in the traditional perspective would be regarded as a bother but not as a resource. Two authors (Wilderer, 2011; Daigger et al., 2011) also name the withdrawal of nutrients or organic matter from wastewater a form of regarding water as resource. Daigger et al. (2011) term this Sustainable Urban Water *and Resource* Management.

Another distinction of SUWM lies in its management approach. Here, integration is a key term. Pahl-Wostl (2007a) defines this integration in water management as including human, technological and environmental perspectives. This is needed because they all are interrelated, for instance the technological part depends on the human component (where is how much water needed at what time and what kind of infrastructure is therefore required), and accordingly evolve together. Looking at each sector, Belmeziti et al. (2015, p.330) differentiate 'technical integration', 'organisational integration' and 'stakeholder integration'. The first focuses on the different utilities for different services (e.g. sanitation or drainage) which would have to be considered jointly in SUWM. Or as proposed by Daigger (2009), the integration of reuse of water, rainwater harvesting and water conservation in one urban water management system. The second emphasizes the need of the collaboration among acting organisations and the third underlines the participation of various stakeholders, accentuating on the resident as a new key actor. Combining Pahl-Wostl (2007a) and Belmeziti et al. (2015) it becomes clear that integration within *and* between each component (human, technological, environment) is part of SUWM.

Furthermore, adaptability is mentioned as a key feature to SUWM. Often a reference to Pahl-Wostl is made, who describes adaptive (water) management as 'the ability to change management practices based on new experiences and insights' (Pahl-Wostl, 2007a, p.51). One element of this is for instance to improve the adaptive capacity of a system which means this system can change in its traits to better encounter current and future difficulties. Pahl-Wostl

(2007a) additionally underlines that adaptability, including learning and experimentation processes, comes along with an 'integrated system design' (p.52). This appraisal reinforces the aforementioned importance of integration to SUWM.

Concerning the infrastructure, a main element of SUWM is decentralization. Decentralization would aid in reducing the dependency on the current pipe network as the infrastructure is implemented locally. Thus, water can be harvested, used and reused locally. The central network is still in existence but not representing the only source of water. By combining central and decentral installations, flexibility can be achieved. Flexibility is needed for facing future uncertainties of demographic and climate change (Kluge et al., 2012). It provides more options for possible courses of e.g. climatic events.

In short, SUWM is a management approach that is integrative and adaptive, incorporates all forms of water, thereby increasing the variability of water sources as well as reducing the efflux of wastewater and combines central and decentral infrastructure.

2.1.2. Concepts Contained in SUWM: Zooming into Adaptability, Integration and Decentralization

Abstract concepts that can be found within SUWM are integration, adaptive management and decentralization. Integration in part refers to the management style. Therefore, management in SUWM can be considered as adaptive *and* integrated. Per Pahl-Wostl (2007b) integrated and adaptive management is needed for dealing with complex 'human-technology-environment systems' (p.561). This approach is more appropriate for dealing with nonlinear and unpredicted evolvement. She names the current water supply system an example for such a complex system with unforeseen development as it has 'led to quite expensive and inflexible systems and to exaggerated expectations of the public regarding the provision of services at no cost' (Pahl-Wostl, 2007b, p. 562).

A key feature of adaptive management is learning (Pahl-Wostl, 2007a; Stankey et al., 2005). As Bormann et al. (1994) defined it: 'Adaptive management is learning to manage by managing to learn' (as cited in Pahl-Wostl, 2007a). It is important to notice that learning in adaptive management is not a spontaneous process but planned and explicitly part of the management. Stankey et al. (2005) underline this 'purposefulness' (p.9) as vital differentiation to an incrementalistic approach. Stankey et al. (2005) furthermore distinguish three elements in the process of adaptive management. First, an introductory setting of the

stage that integrates information about the problem, examines the political realm and concludes on lacking knowledge. The second element is to specify an experiment. And the third element brings in the adaptability by referring the results of the experiment back to the problem and deducing changes in management practice.

Adaptive management came into being on the recognition that knowledge about the future is limited. Being able to learn then becomes an essential asset of the management (Pahl-Wostl, 2007a). Further factors supported the idea of adaptive management in the field of natural resources. These factors are: 'less resilient and more vulnerable ecosystems, more rigid and unresponsive management agencies, and more dependent societies' (Holling (1995, p.8) as cited in Stankey et al., 2005, p.6). These three elements can well be related to the traditional urban water management approach and the new aims that can be found in SUWM (as explained above): on the one hand, the natural water system is partly overused, the management and infrastructure is central and hierarchical and inflexible but, on the other hand, the society depends on a functioning water distribution system.

As pointed out by Stankey et al. (2005) integrated information is a crucial starting point for adaptive management. Likewise, Pahl-Wostl (2007a) emphasizes how adaptive and integrated management have to go hand in hand. Integration describes the 'process of combining two or more things into one' (Cambridge Dictionary, 2017). As explained in the definition of SUWM and seen here by the term 'things', an integration is rather unspecific and can relate to anything. Therefore, the term needs to be applied to urban water management and to the distinction into *stakeholder*, *technical* and *organisational* integration as made above:
General notions to an integrated approach to urban water management imply to take a holistic perspective that includes e.g. stormwater, ground- and surface water and recreational areas (one hydrological cycle) and simultaneously health and quality of life issues of urban residents (Feilberg and Mark, 2016). Moreover, integration requires the inclusion of various *stakeholders* which adds to a sustained and rich information base and for instance with regard to planning, concerted action between urban planning and climate change adaptation or more generally speaking integration of various sectors, such as water supply, flood management and spatial planning (Feilberg and Mark, 2016; Pahl-Wostl, 2007b). The *technical* aspects relate to the integration of a drainage and sanitation system alone to a system that technically includes all aspects related to water which are for instance rainwater, reused water and the natural water (Belmeziti et al., 2015). This technical integration underlines the need for a

respective *organisational* integration, which refers to the organisations that are an active part of the project and the implementation. Their expertise needs to be combined to achieve a technical integration.

Generally speaking, integration in SUWM thus describes the different perspective that needs to be taken (as anyone involved is required to broaden his or her horizon), and the integration within and between actors, affected stakeholders and technique.

The physical decentralisation of the water system means that water which is locally available is utilized (Arora et al., 2015). Local water is made usable through e.g. rainwater harvesting or water recycling. With such system, the water sources are diversified and a fit-for-purpose approach is made possible. By rejecting the provision of the same quality for all usages, a decentralized system can help overcome the inefficiency of a centralized system that supplies potable water for any usage (Arora et al., 2015). As likewise pointed out by Wilderer (2011), a decentralized system would not replace the centralized infrastructure but rather add to it and turn it into a hybrid water service system (Arora et al., 2015). Makropoulos and Butler (2010) define decentralised (or distributed) systems as those that are employable for the level of new housing developments, but incorporate in-house applications in their definition. A link is made between the trend towards decentralized systems and a 'local stewardship of the environment' (Makropoulos and Butler, 2010, p.2796). Both Arora et al. (2015) and Makropoulos and Butler (2010) mention drawbacks of a decentralized system in form of its energy intensity or trade-offs with other land use.

2.1.3. Assumed Benefits of SUWM

To evaluate the desirability of an upscaling of SUWM, one needs to be acquainted to the assumed benefits that come along with the implementation of SUWM. Two ideas are shortly explained here: environmental sustainability and climate change adaptation. The two concepts are related as Hurlimann et al. (2017) point out: in pursuing the achievement of sustainability, it is needed to regard the impacts of climate change.

Environmental Sustainability

Environmental sustainability can be defined as a present consumption that does not threaten requirements for future generations (Somogyi, 2016). Water is part of the urban metabolism

which implies that '[t]he way in which water provision is organised has considerable consequences for the ecological performance of a particular landscape, hence for the sustainability of cities' (Naumann and Bernt, 2009, p.461) showing the potential of urban water management to increase environmental sustainability.

Applying the sustainability concept to urban water management, this does not only mean that no more water than can be regenerated should be taken from water bodies but also that for instance the treatment of wastewater is energy neutral and that the amount of wastewater does not overcharge the environment (Spiller, 2016). Spiller (2016) furthermore emphasizes the inter-generational equity as a main contributor to the overall sustainability, which indicates that in the current urban water management, the future water quality and quantity needs to be considered.

Marlow et al. (2013) describe SUWM as an approach taking environmental concerns into account, which can have the concrete aim of water resource preservation (Belmeziti et al., 2015), thus outlining that SUWM not only adds to but emphasises environmental sustainability and thus contributes to securing future water supply.

Climate Change Adaptation

Adaptation to climate change is defined as: 'the adjustment in natural or human systems in response to actual or climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC, 2007, p.6). Van Buuren et al. (2013) draw on this definition to conclude that the anticipation of climate impacts is threefold: 'minimizing potential damage; coping with the consequences of impacts; and taking advantage of opportunities' (p.30). Key components of SUWM (see Section 2.1.1.) are the use of otherwise unused water sources and facilitating a natural water cycle. The first element, use of unused water, can be linked to the perspective of *taking advantage*, as for instance increased precipitation can be used as additional water source. The second element, facilitation of a natural water cycle, is likely to aid in *coping with the consequences* as storm- and rainwater would be allowed a natural drainage. Vice versa, the cases of drought or decreased precipitation can be addressed by using wastewater as source, thus increasing efficiency of water usage. With this variability, *possible damage* of the consequences is *reduced*. Potential harm caused by changes in temperature or precipitation, such as flooding if no natural drainage is allowed, or water scarcity in a dry period with only one source of water available, is thus avoided and it can be adapted to the different circumstances. Moreover, potential benefits are employed by using additional sources of water.

Scheele et al. (2008), referring to water management, describe that adaptability is achieved by modularity or the so called modular principle as single modules can be installed or turned on and off independently of other subparts. Together these parts form an integrated and comprehensive system but technological path dependency is reduced and conversion is easier.

2.2. Recognized Drivers and Impediments to the Implementation of SUWM

In this section, the drivers and impediments to the implementation of SUWM as found in a literature research are described.

2.2.1. Drivers and Opportunities for SUWM

The unsustainable use of water resources and consequent appeal to a novel approach of water management has been an issue for a while (Gleick, 1998) and is still the major root of advocating for SUWM. The implementation of SUWM is deemed as crucial in facing future water-related problems (Hurlimann et al., 2017) and increasing a city`s resilience to be prepared for climate change (Wong and Brown, 2008). Some regard SUWM as an approach encountering worldwide problems, including the already mentioned climate change and environmental impacts but also population growth (van Meene et al., 2011). An impression of SUWM is given as all-embracing saviour. Thus, SUWM is a fashionable approach (Bell et al., 2017) that encompasses other popular approaches, which are Integrated Urban Water Management and total water cycle management (Hurlimann et al., 2017; van Meene et al., 2011). Awareness of the inability to meet future challenges and the end of the infrastructure`s life expectancy (Hering et al., 2013) place the emergence of SUWM in a beneficial slot.

Naumann and Bernt (2009) describe how the water network is in a process of transformation, including privatization, liberalization and ecological modernization. In some parts of Germany, there is the additional concern of shrinking cities, implying that the basic conditions for the urban water network are not given anymore and thus pave the way for a novel water network (Naumann and Bernt, 2009). Decreasing use of water infrastructure eventually leads to higher maintenance costs and demands a short-term thinking and adjustments from a sector that is used to a long-term expansion (Naumann and Bernt, 2009). This underlines the obstacles of a central and inflexible water infrastructure and exposes a window of opportunity. Furthermore, with differing circumstances, for instance concerning the growth or

shrinkage of a city, no universal but more individual und thus decentralized solutions are required (Naumann and Bernt, 2009). Ott et al. (2016) confirm that there is a pressure for change due to the aforementioned reasons of demographic change, climate change and increasing energy prices.

This is similarly mentioned by Scheele et al. (2008) who name various driving forces for a transformation of net bound water infrastructure. These are: *sustainable development* which is lacking in the current system due to intensive energy and resource use, regarding used water as waste, high path dependency and missing adaptability; *new technologies* such as new treatment procedures or communication technologies (and IT) that are supported in their implementation via de- or semi central system components at the same time bettering the diseconomies of scale; *climate change* as the water industry will be particularly effected for the reasons explained in Section 1.1. but also side effects such as an increase in energy pricing; *demographic change* that in its intensity is specific to Germany; *urban development/revitalisation of urban brownfields* with a discussion of the city`s role for implementing new technologies and the potential of regeneration processes for introducing novel (and decentral) system components; and finally the *integration of infrastructural and spatial planning* where the traditional infrastructure-follows-urban development is questioned.

Marlow et al. (2013) see opportunities of cost-reduction in a fit-for-purpose use of water in using potable water solely for potable needs. Whereas Ott et al. (2016) state that while efficiency is likely to increase, more intensive coordination would be required and the cost-benefit impact remains unclear.
Implementation of SUWM in practice for the most part happens when an area in a city is newly developed, hence, instead of expanding the central system, a different water infrastructure is constructed. Especially in an urban area, there are many sectors that can make use of non-potable water, such as industrial demand or irrigation of green areas (Marlow et al., 2013). Next to new developments or conversion areas, Ott et al. (2016) name buildings demanding restructuring as potential areas for introducing SUWM.

Thus, environmental awareness, increased efficiency in water usage (through SUWM) and urban developments (revitalisation or new developments) can be named as main drivers for the implementation of SUWM.

2.2.2. Recognized Impediments

It is important to be aware of barriers to work on how they can be overcome and additionally, to focus in the cases on whether these barriers were present or have been overcome. First, a broader systems perspective (on adaptive water management) is taken, followed by a SUWM perspective and hereafter SUWM in Germany perspective.

A limit to introducing something new lies in the inflexibility of the currently existing system. This inflexibility is visible in the structure of decision-making but likewise in the infrastructure which was built up to a great expansion to last for a long time and which represents high expenditures (Pahl-Wostl, 2007a). Adding to this, Marlow et al. (2015) state that the considerable life span of infrastructure can lead to lock-in effects. They proceed in explaining that due to this long life span an interdependence between the management of infrastructure and framing governance exists which attributes to the lock-in effect. It is highlighted that these lock-in effects have both an institutional and technical aspect (as mirrored in the beforementioned interdependence). Brown et al. (2011) refer to this as entrapment, a phenomenon not unusual in large systems that are of socio-technical kind (such as energy or water).

Zooming in to SUWM, Brown and Farrelly (2009) found the barriers to implementation rather within the socio-institutional scope than in the technical scope. In a review of various articles, they identified barriers that could be related to inter- and intra-organisational capacity, external institutional rules and incentives and to a much lesser extent human resources. The barriers found most often were: ‘uncoordinated institutional framework’, ‘limited community engagement, empowerment and participation’ and ‘limits of regulatory framework’ (p.842-843; see Table 2, also as example for the institutional scope). The authors emphasize that these barriers are interrelated and since they are often found within institutions, fundamental change within these institutions is needed. A common term used for the institutional barriers is that of institutional inertia (Brown and Farrelly, 2009).

Marlow et al. (2015) support this argument by stating that many challenges arise since an implementation of SUWM happens within an existing legal framework and appropriate regulations and guidelines are missing.

Table 2: List of barriers to the implementation of SUWM as identified by Brown and Farrelly (2009) (modified after Brown and Farrelly, 2009).

Barriers as found in a literature research by Brown and Farrelly (2009)
Uncoordinated institutional framework
Limited community engagement, empowerment and participation
Limits of regulatory framework
Insufficient resources (capital and human)
Unclear, fragmented roles and responsibilities
Poor organisational commitment
Lack of information, knowledge and understanding in applying integrated, adaptive forms of management
Poor communication
No long-term vision, strategy
Technocratic path dependencies
Little or no monitoring and evaluation
Lack of political and public will

For Germany, Wilderer (2011) names the increasing complexity of the system through the variability of water flows that requires high expertise and can unlikely be taken over by property owners. Consequently, an implementation of SUWM would have to be accompanied by the training of personal and a sensory system that allows for monitoring from the distance. He terms this an operational risk. A further risk is of material nature. Wastewater can contain chemical substances or pathogens that are potentially threatening to the environment. There is still a high need to ensure these are completely removed when reusing water.

Kluge et al. (2012) discuss the progress of Germany towards sustainable water management with focus on integrated solutions. They name the challenges of integration requiring a new intersectoral coordination and communication which is not yet in place and the lack of a regulative framework.

Schramm et al. (2017) also refer to legislation by stating that a legislative mandate is missing. Moreover, they point out that the water management is performed by separated departments leading to narrow organisation and fragmented responsibilities. Adding to this is an 'uncertainty around performance and cost' (p.2) which is adverse to a fast and positive implementation. Altogether, Schramm et al. (2017) conclude that institutional barriers are the most influential.

Ott et al. (2016) name sunk capital in the existing infrastructure and simply the costs of building up a new system as an obstacle. Furthermore, there is strong institutional path-

dependency as the German water system began 150 years ago with, from the start, a strong focus on the quality of drinking water.

In sum, the literature suggests that main obstacles to the implementation are infrastructural and institutional inertia and the risks and challenges that come along with a new system.

2.3. Setting the Stage for Clarifying the Significance and Relevance of SUWM in Germany

In this section, the theoretical concepts needed for assessing the significance and relevance of SUWM and defining the examined micro-scale projects are presented. These are namely transitions with an emphasis on micro-transitions and upscaling.

2.3.1. Transition, Micro-transitions and SUWM

A transition is a process of change in which a system transforms its structure. It is a long-term development or co-evolution of different developments (Rotmans et al., 2001). A key attribute in transition theory are the distinct developments within a multi-level setting of function (van der Brugge et al., 2005). There is the macro-, meso- and micro-level (see Figure 6). The macro-level concerns the 'socio-technical landscape' (p.166), which is about larger matters such as politics or nature. The meso-level regards the prevailing regimes, which are the rules or institutions being followed (van der Brugge et al., 2005). The micro-level concerns the so-called niches, these can be individuals but also the implementation of new technologies or local practices that deviate from the common regime (van der Brugge et al., 2005). Brown et al. (2011) refer to such developments at the micro-level as micro-transitions.

Therefore, within this thesis, innovations concerning practices and technologies in urban water management that are locally restricted and do not apply to the entire system are then called micro-transitions. Such practices can be local stormwater harvesting or a decentralized recycling of wastewater (Brown et al., 2011).

According to Schramm et al. (2017) innovations can refer to: 'the supply of different types of water, the separation of wastewater streams and the use of wastewater as a resource' (p.1). Thereby, innovations can concern the technological aspect as for example nanofiltration or the managerial aspect which include the reuse of water and separation of sources (Schramm et al., 2017).

Ott et al. (2016) define innovative water infrastructure systems as: those systems that apprehend wastewater in parted streams with consideration of potentially distinct treatment and usage; a regaining and usage of heat; and exploitation of constituents along with techniques that are not (yet) established. These subsystems correspond to so called technical modules.

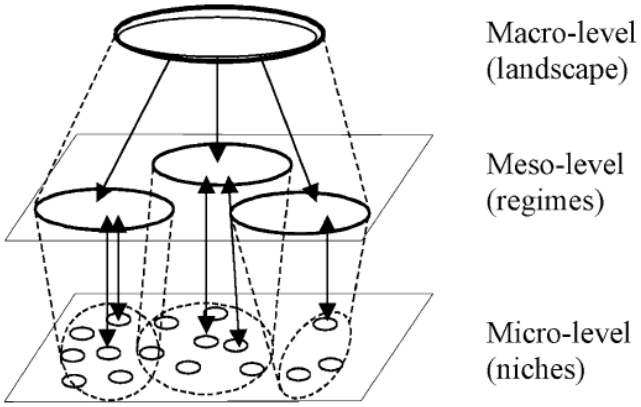

Figure 6: The multilevel concept of transitions, showing the interaction between the different levels (Van der Brugge et al., 2005).

A transition in urban water management that happened on a larger level is for instance the shift from pumps or wells to a large public water network. This incorporates a shift from low technology to high technology (de Haan et al., 2015). De Haan et al. (2015) emphasize that a transition is not achieved by adding new services to the existing infrastructure and regime but by introducing new functions that are not conforming to the existing regime. An example of such a transition is a water cycle city (regarding the natural water cycle) or water sensitive city (urban design that is water sensitive) (de Haan et al., 2015).
Koziol et al. (2006) name system alternatives that in the long term, with changing conditions, are more sustainable, as prerequisite for a successful transition. Important principles for these system alternatives are: adaptability, being receptive to transformation, modularity, ecological embedment, and economic and social compatibility.

A second major characteristic of transitions is the multi-phase concept. Rotmans et al. (2001) define four phases (see Figure 7): the predevelopment, the take-off, the acceleration and the stabilization phase. In the first phase, there is no visible change of the system. In the take-off, the beginning of a shift becomes observable. In the third phase, there is a convergence of different changes such that the bigger structural changes become visible. During the stabilization, the dynamics decrease and the new system is established. Usually, a transition

lasts at least 25 years (Rotmans et al., 2001). During the predevelopment, the meso-level takes an inhibiting role, wanting to keep the situation unchanged. When there is a modulated micro- and macro-level with ideas crossing between the levels, the take-off phase is attained. The acceleration phase is reached when the evolvement has been accepted by the meso-level and receives support also from this level. The stabilization is characterized by the establishment of a new regime (van der Brugge, 2005).

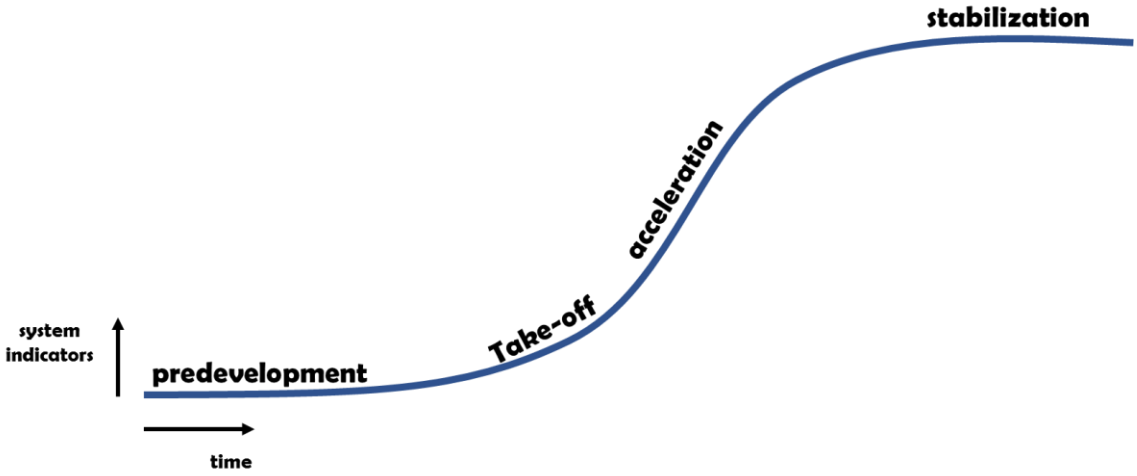

Figure 7: The four phases of a transition (modified after Rotmans et al., 2001).

Further key features of transitions are the multi-actor and multi-factor setting (Elzen and Wieczorek, 2005). The scope of actors for a micro-transition towards SUWM can include companies that implement the required infrastructure, the consumers or building-owners that initiate the implementation. The multi-factor feature as described by Elzen and Wieczorek (2005) means that various factors ('technical, regulatory, societal, and behavioural change', p.655) influence and induce the change happening. For this case, factors could be changing behaviour or demands of the individual, somewhat overlapping with a societal awareness of the need for a more sustainable handling of water, regulatory measures such as subsidies for implementing e.g. rain harvesting stations and the sheer existence and thus availability of the techniques for SUWM (rainwater harvesting gadgets, local water treatments, etc.).

2.3.2. The Affair of Upscaling

SUWM is hitherto a local matter. One main feature is the decentralized infrastructure (see Section 2.1.1.) which automatically makes it local. Additionally, it is simply not existent on a larger scale (Brown et al., 2011; Schramm et al., 2017). Some authors state that SUWM is essential for achieving resilience towards climate change (Wong and Brown, 2008) and for

dealing with future water-related problems (Hurlimann et al., 2017). This would implicate a desirability of an upscaling of SUWM. Whether an upscaling of SUWM is desirable is discussed in Section 4.3.3..

A transition can only be completed successfully if all three levels (micro, meso, macro) meet at one point and positively reinforce each other (van der Brugge, 2005). The micro-level can be influential as being the starting point of 'the new', where experimentation and learning happens and can take the form of a proliferation, thus extending to the meso- and macro-level (Rotmans et al., 2001). This can be seen as a form of upscaling. The relationship is reciprocal, also the macro- and meso-level can influence the micro-level if for instance the political culture or prevailing beliefs change (Rotmans et al., 2001).
This process of turning from something small into something big - ergo, the process of upscaling – depicts the traversing of the four phases, predevelopment, take-off, acceleration and stabilization and the accompanying interaction of the different levels (see previous section).

The process of governing a transition is called transition management (van der Brugge, 2005). To actively support a transition, possibly steer and facilitate it, hence to concretely upscale SUWM, two perspectives on transitions can be taken: The complexity perspectives (Loorbach, 2010) and the political perspective (Huitema et al., 2011). Without going into detail, the main difference is that transition management from the complexity perspective draws more on the influence of the structure of a system to induce change, which is the governance approach (Loorbach, 2010). Whereas the political perspective sees high potential in the acting of policy entrepreneurs for inducing change (Huitema et al., 2011). From a transition theory point of view, there are consequently two aspects for the upscaling of SUWM: Adding nation-wide political change (e.g. in terms of regulation, laws) to the niche innovations and advocating for SUWM through policy entrepreneurs who could for instance form coalitions between stakeholders including technology developing engineers, project managers and the municipality.

De Boer and Zuidema (2013) talk about the energy transition in the Netherlands and emphasize the importance of linking niche projects to the area as precondition for a successful upscaling. This approach can be translated to SUWM as its functions can potentially be interlinked to spatial functions that are in high need of water or have a high discharge of water

or a large catching area. The first could for instance be greenhouses that use water for irrigation, the second could be large buildings such as a stadium. Looking for these options and connecting them can create an added value for all actors. Thus, synergies are created, a robust foundation is built and new projects are stimulated (De Boer and Zuidema, 2013). This makes an area-based approach a further opportunity for the upscaling of SUWM and moreover, strengthens the link to spatial planning.

2.4. Conceptual Framework

In the following figure (Figure 8), the theoretical aspects of this thesis are put into a conceptual framework to show how they interlink. The setting of the research is the interaction between the natural environment and urban area. Here, urban water management is situated. In this urban water management, it is looked at a potential transition from the conventional practices to novel practices containing at least to some extent SUWM. What exactly the finalization of the transition looks like can by no means be predicted.
The precise loci examined in more detail are SUWM itself, innovative micro-transitions and their upscaling which connect to the take-off and acceleration phase of a transition. Opportunities and barriers for an implementation of SUWM and hence to an upscaling of SUWM are investigated. But also the desirability of an upscaling, among other influenced by the benefits of SUWM, are deliberated.

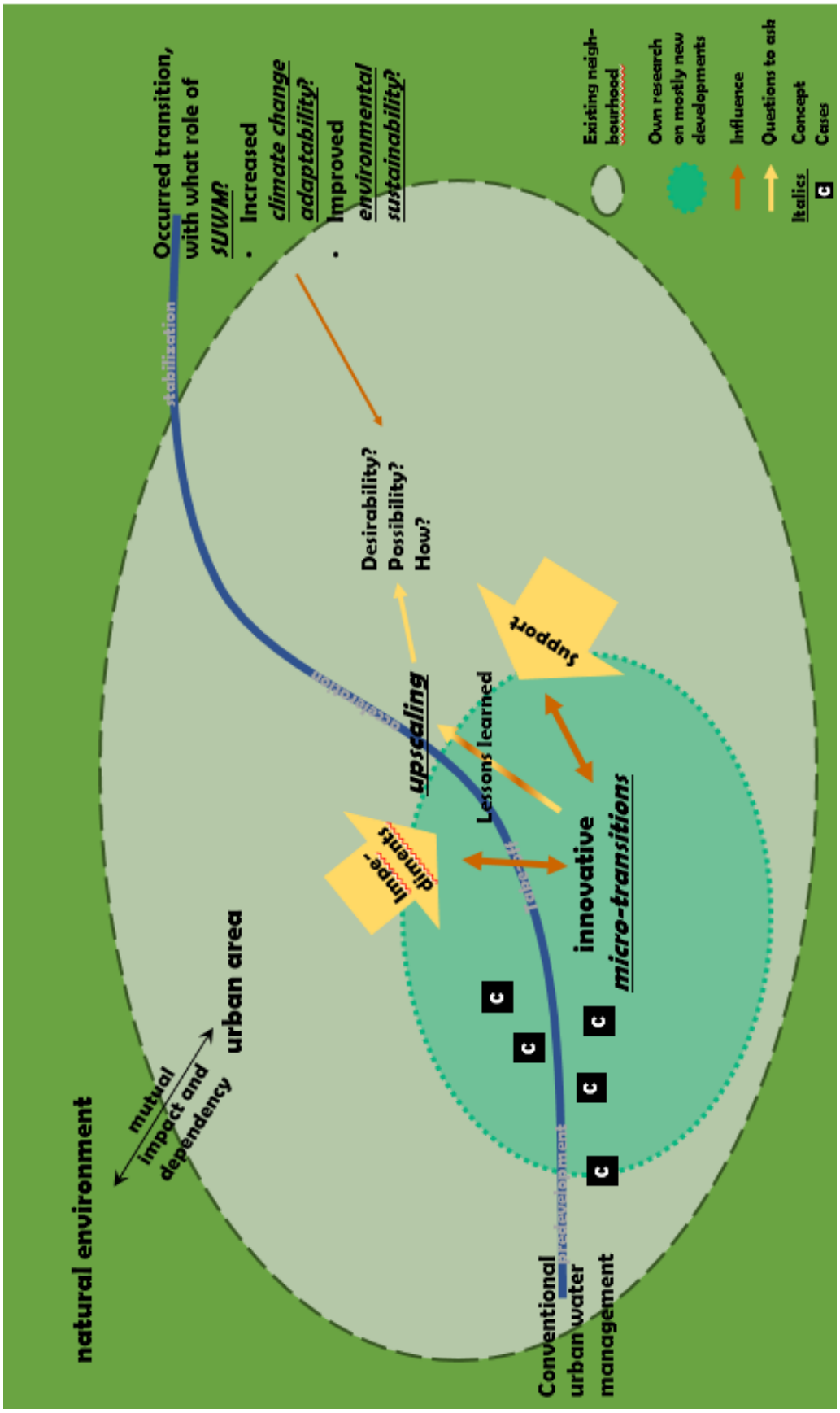

Figure 8: Conceptual Model (author, 2017).

3. Methods

In this chapter, the methodological background of this thesis is explained. First, the reasoning behind the research design, methods and data is disclosed. Second, the chosen methodology and methods are explained in more detail. Third, the data analysis and data quality is discussed.

3.1. Obtaining Meaningful Data

In this thesis, a comparative research is conducted because the aim and main question is to find conditions to the implementation of SUWM that are valid in different German urban contexts. By comparing different cases, such conclusions can be drawn (O`Leary, 2004). In this work, case studies are compared because they generate detailed knowledge about a certain case (O`Leary, 2004) and thus, a comprehensive understanding of the impeding and supporting conditions to the implementation of SUWM. Furthermore, the role of SUWM in Germany is examined to be able to discuss the possibility and desirability of an upscaling of SUWM. By this, the primary research question: *What are the supporting and impeding conditions to an implementation of SUWM in the cities of Germany and what does this imply for a potential transition in urban water management?* is answered. To describe and characterize SUWM as a new management approach in German cities, descriptive data produced by qualitative research is needed (Taylor et al., 2015).

The used methods for obtaining data are document analysis and semi-structured interviews. Semi-structured interviews allow for a detailed questioning of experts and follow-up questions if regarded necessary (Di Cicco-Blom and Crabtree, 2006). With interviews and document analysis qualitative data is generated. This qualitative data provides a meaningful and better understanding of the cases which is more appropriate to answer the research question as it aims at understanding how to implement SUWM in Germany and what relevance and significance SUWM has in Germany. Quantitative data that aims for instance at proving a relation (Flick, 2009) would be less appropriate. The qualitative data is then analysed thematically (O`Leary, 2004).

It is essential to conduct qualitative research within a theoretical framework to ensure its compliance to existing theories (Taylor et al., 2015), thereby enabling to connect findings to theory and give validity and substance to a sought generalisation (Mjøset, 2006; Rose, 1991). This theoretical framework is given in the previous chapter and regards the aspects risen by the theory-based sub-questions that help answering the main research question.

3.2. Comparative Research

To find supporting and impeding conditions that provide valuable lessons for all of Germany and are not only valid in a specific urban context or case, it is necessary to draw on various contexts and find conformances between these cases. This is best achieved by a comparative research that has the 'search for similarity and variance' (Mills et al., 2006, p.621) as its main goal. By such 'search for similarity and variance' an experimental method, where the setting can be changed to inspect what difference it would make and thus find causal relations, is supplanted. Comparing allows to deduce causation based on similarities and difference between cases (Denters and Mossberger, 2006). Sartori (1991) explains that the main purpose of comparison is to achieve an explanation and understanding that is controlled precisely by the comparison. Additionally, comparison facilitates learning from the respectively other case (Denters and Mossberger, 2006). It is needed to find causations for answering the first part of the main research question - *what are the supporting and impeding conditions to an implementation of SUWM in the cities of Germany* – as the found conditions apply for several cases, hence likely for more German cities; but also the second part of the main research question- *what does this imply for a potential transition in urban water management* – which is defined by the found conditions. Learning can be important for the second part of this research question as it can accelerate the upscaling but also makes a statement concerning the possibility of an upscaling, in terms of what learning aspects can be transferred to other cases.

To find impeding and supporting conditions to the implementation of SUWM, in-depth knowledge is needed of cases where such implementation has happened. Five case studies in five different localities are conducted to gain this in-depth and locality-related knowledge. Thus, the research design of this study is the comparison of case studies.

When comparing cases, differences, similarities and patterns are synthesized (Goodrick, 2014). This synthetization and detection of causalities assists the finding of impeding and supporting conditions and potential other important aspects that account comprehensively concerning the implementation of SUWM.

The comparison is conducted across different cities in Germany to achieve as generic conclusions as possible within this research frame. Cases have been selected on basis of the dependent variable (or outcome). A limitation to such selection is in the logic of explanation as it is assumed that shared factors lead to the outcome but it is not checked if cases that do not come to the same outcome possibly also share that factor (Geddes, 1990).

The outcome is the same in each case, a successful implementation of an innovative water management approach. The projects themselves (for instance the implemented technique) and the cities are different. Thus, common patterns found across the cases have the potential to allow for comprehensive conclusions and indicate possibilities of transferring results (Goodrick, 2014).

3.3. Case Study

In a comparison, various units (or as in this thesis, cases) are compared to assess similarities and differences (as explained above, Denters and Mossberger, 2006).
A case study is a research strategy supporting the close and detailed examination of a case. To collect data, it is usually drawn on different methods (Eisenhardt, 1989). In this research, the main data collection has been conducted via semi-structured interviews. Next to this, a document analysis (on documents such as newspapers or brochures) has been used.

Cases that fulfil the requirement of representing an innovative project implementing sustainable urban water management as defined in Section 2.1.1. have been selected. Following aspects were regarded when selecting the cases: Cases are placed in different locations but share the unit of analysis, meaning that all are placed in an urban context (defined in administrative terms) and contain either several housing complexes or housing units. The cases are newly developed areas or contain parts that were newly developed. The techniques applied in the cases differ. A decentral rainwater management is a part of SUWM but to be selected as case, the aspect of reuse had to be existent.
The case of Hannover is older than the other cases, thus allowing for the inspection of temporal evolvement. Here, some of the implementation happened in existing buildings which is kept in mind when concluding on impeding and supporting conditions and can be helpful for assessing which findings can be transferred to established water infrastructure.
The dependent variable is a successful outcome equalizing the realization of the implementation of SUWM. A successful outcome is defined as a case that has been finished at least partly in its construction and is in these parts inhabited. Independent variables are those that are affecting the dependent variable. They are examined to understand the causes of the dependent variable (O'Leary, 2004). The independent variables are the measured variables influencing the dependent variable (O`Leary, 2004). In this research, the independent variables correlate to the coding categories which are Institution, Financial Aspects,

Management, Infrastructure and Aim. It is also looked directly at mentioned influences (see Table 4 for all coding categories and associated codes).

The cases are the Jenfelder Au in Hamburg, the Hohlgrabenäcker in Stuttgart, the project DEUS 21 in Knittlingen, a passive house in Frankfurt and the Öko-Technik-Park in Hannover. See Section 4.2. for a description of the cases. For each case, a graph has been designed, based on both the interview and document analysis, where the stakeholders, their connections and their functions are presented. Through this visualization, a better overview of the cases has been created that facilitates the comparison of the different settings, such as responsibilities or initiation of the project. There is no claim of completeness for the graphs. They are based on the analysed documents and interviews but there can be undetected gaps.

3.4. Semi-structured Interviews

Interviews are used as data collection method for the case studies (De Vaus, 2001). By interviewing, detailed information can be gained from the interviewee. The interviews are semi-structured which means the questions are open-ended and there is room for further questions or clarifications (Di Cicco-Blom and Crabtree, 2006). The principal sub-question to be answered with the interviews, is: *What are the impeding and supporting conditions to an implementation of SUWM as defined within the research on the cases in Germany?* The chosen interviewees were or are directly involved in the project and are therefore the best source of information as they themselves have experienced impediments and support. At the same time, they are the experts, knowing about other projects, the usual procedures and other circumstances as for instance legal issues. Therefore, they know what makes SUWM projects distinct, also when contrasted to 'normal' projects.
As explained, the semi-structured interview allows for follow-up questions, hence, if the interviewer perceives that the conditions are not yet clear or not all aspects have been covered, he is free to dig deeper and try to obtain more information. At the same time, it can be ensured that certain, predefined topics are incorporated in the same manner for all interviewees and that the predefined aspects from theory are covered.

For each case, it was aimed at three interviews that have been conducted via skype or telephone. A combination of interviewees has been selected with the aim of involving the planning, private and public sector and thus regard the potential different perceptions as different origins of people can make them perceive different opportunities or barriers. Such

combination and number has not been achieved for all cases due to availability of interviewees and in the end, time constraints.

When discussing the findings, the interviewees are referred to by their number and the city of their project to indicate the different cases. All interviews have been conducted in 2017 which is not further indicated in the references to shorten the reference and facilitate reading. The interviewees are presented in Table 3.

Table 3: Overview on the interviewees, their functions and time of the interviews (author, 2017).

Interviewee	Function	Project	Date and Medium
Interviewee 1	Project manager of operation from Hamburg Water Cycle	Hamburg	2nd of June 2017, telephone
Interviewee 2	Scholar	Hamburg	2nd of June 2017, telephone
Interviewee 3	Employee at the District Office Wandsbek	Hamburg	9th of June 2017, telephone
Interviewee 4	Engineer at participating engineering bureau	Stuttgart	29th of May 2017, skype
Interviewee 5	Project manager at the responsible urban development Ltd	Stuttgart	6th of June 2017, telephone
Interviewee 6	Employee at the Municipality of Stuttgart	Stuttgart	6th of June 2017, telephone
Interviewee 7	Scholar	Knittlingen	23rd of June 2017, telephone
Interviewee 8	Employee of the municipality of Knittlingen	Knittlingen	19th of June 2017, telephone
Interviewee 9	Scholar	Frankfurt am Main	4th of July 2017, telephone
Interviewee 10	Employee from a sub-company from the drainage company in Hannover	Hannover	12th of June 2017, telephone
Interviewee 11	Engineer at participating engineering bureau	Hannover	14th of June 2017. telephone

3.5. Document Analysis

Document analysis is used to gather context and background information (O`Leary, 2004) which can be useful for finding potential impediments or support. They can show additional factors that are not illuminated in the interviews. Thus, they can deepen and enrich the knowledge and data about each case. Document analysis includes, next to the analysis of data itself, the collection and review of data encountered in documents. This data represents primary data as it is regarded as source of data (O`Leary, 2004). The type of documents reviewed and analysed for the cases include newspaper articles, personal communication in

form of e-mails and pamphlets. Apart from enriching the information about each case, these documents can reveal more about the aim of the project or public perception and as such contribute to the discussion about upscaling SUWM. Such documents can be biased as they represent a certain interest, which has to be kept in mind when analysing the documents, for instance by clarifying if opinion or facts are given and what the author`s background and aim is (O`Leary, 2004). The documents are investigated according to the same codes as the interviews (see Table 4). In the documents, not all codes have been found to equal extent as in the interviews. But it is looked out for the same codes as they aid in answering the research questions. A list of all documents can be found in Appendix A.

3.6. Analysis and Quality of Gained Data

The interviews have been transcribed for further analysis. This analysis is a content analysis as it is focused on the content of the answers of the interviewees to assess the meaning of what has been said (O'Leary, 2004). Considering the manageable number of interviews, coding has been conducted manually.

Coding is essential as it structures the interviews according to themes and facilitates answering the research questions (O'Leary, 2004). For coding, it is followed Saldaña (2009): He describes a code as a 'summative, salient essence-capturing' word or phrase (p.3). There are - in increasing detailedness - categories, codes and subcodes. By attributing codes to a text, data is assembled and analysed. The process of coding is repetitive with various so-called cycles at which new codes can be generated and/or old codes dropped (Saldaña, 2009). A table with categories, codes and subcodes has been prepared and has constantly been updated during the coding process. In-vivo coding, where codes arise from and thus equal words or phrases used by respondents (Saldaña, 2009), has also been part of the coding process. Furthermore, a code book with definitions of codes as suggested by Saldaña (2009) has been created (Table 4).

The outcome of the coding are themes. Themes explain the meaning behind a code (Saldaña, 2009). Here, the themes are the impeding and supporting conditions and transition-related aspects that are asked for in the research questions. In the findings (Chapter 4), the themes and not the detailed coding results are described and discussed.

The quality of the data needs to be assured to give legitimacy and credibility to the research (O`Leary, 2004; Flick, 2009). O`Leary (2004) describes that to make a (qualitative) research

credible, there has to be an indication of how to deal with subjectivity, methodological consistency, truth, applicability, and accountability. How to fulfil these criteria is decided by the researcher (O`Leary, 2004). In the following, it is described how credibility is to be achieved for this thesis based on O`Leary (2004).

Objectivity is deemed as impossible and self-reflection or reflection through outside-positioned people is used. In this thesis, it is acknowledged that certain research interest exists, the influence of which is dealt with in a self-reflection (see Chapter 6).

Accountability is attained by being open and transparent about the research process, as is inter alia done in this chapter, to make the research auditable, comprehensible and reproducible. The interview guide, codes and other important methodological documents can be found in this chapter (Table 3 and 4) or in the appendix (Appendix A, B and C).

Methodological consistency is addressed by being consistent, systematic and well-documented in the research procedure. For instance, the process of content analysis is documented in this chapter and the used codes for analysis are disclosed.

Authenticity is provided by a precise and reflexive performance of research. Similarly to the consistency, authenticity is achieved by working systematically and well-documented and by theoretically discussing the findings.

To be transparent, traceable, consistent and self-reflective are here the main means to achieve a good quality of data analysis and research.

Table 4: Coding Book: Codes that have been used for the analysis of documents and interviews (author, 2017).

CATEGO-RIES	CODES	DEFINITION
INSTITUTION	Laws	Specific laws that are named or reference to the law and regulations in general
	Supporting money	Any subsidies or funds mentioned
	Private	Any reference to private property or private companies (also linked to responsibility)
	Public	Any reference to public property or public companies (also linked to responsibility)
	Responsible	Any indication of responsibilities for e.g. water supply, construction, maintenance, …
	Human institution	Prevailing of norms and attitudes ('regime')
FINANCIAL ASPECTS	More expensive	Anything (e.g. construction, maintenance, planning) that is more expensive than a 'regular' project
	Cheaper	Anything (e.g. construction, maintenance, planning) that is cheaper than a 'regular' project
	Who is paying	Who is paying how big a share and why so (fund, contract, …)
	Difference to residents	What is financially different for the residents
MANAGEMENT	Cooperation	Any indication for a cooperation between different parties/companies/stakeholders
	Communication	Any indication of how it is communicated (between or within parties, towards citizens)
	Exchange of information	Indications of how, why and when information is transferred
	Sectors	Mentioned sectors
	Modifiable infrastructure	Indication if infrastructure can be altered or not or modified for being applied elsewhere
	Showed robustness	If already 'survived' an extreme event
	Total water cycle	Reference to total water cycle
	Above the needed	Anything that is more than the legal/technical/etc. minimum
INFRASTRUCTURE	Central	Indication to central water infrastructure
	Decentral	Indication to decentral or local water infrastructure
	Interconnection	If central and decentral are in any way connected
	Problems	Have there been, are there, or is there a potential of future infrastructure or technology related problems
	New	Is the technology new
	Research	Any relation to research (if existing or wished for)
AIM	Why	What reasons are given for the project
	Conditions that led to solution	Any conditions that led towards the solution
	What is wished to be achieved	What is stated as being wished for
LESSONS LEARNED	Do differently	What would be done differently if the project was to happen again
	Do in the same way	What would be done alike if project was to happen again
	Learned from other	Any reference to what had learned themselves from other projects
	Transferability	Any reference to what can or cannot be compared/transferred to other projects (or already has been transferred), includes recommendations to others
INFLUENC-ING (CASE-SPECIFIC)	Slower	Any factor mentioned that slowed down/hindered/influenced negatively the project
	Faster	Any factor mentioned that fastened up/supported/influenced positively the project
	Comparison to traditional system	When comparisons to the traditional system are made or a statement about the 'normal' system/'normal' projects are made or what is new
INFLUENCING (GENREAL)	Past	Any reference made to past conditions or past happenings
	Future	Any reference to future evolvements or predictions
	Situation now	What is the current situation (e.g. a certain law or size of projects)
	Influencing factors	What is mentioned as influence to the implementation of novel techniques in general or to the examined project

4. Implementing SUWM in Germany: Where it Stands and How it Is Conditioned

In this chapter, the research context - urban water management in Germany - is explained to be able to embed the cases within. The five cases are presented in detail and the findings from the interview and document analysis are set out and discussed. In this, the practice-related sub-questions are answered. These are: Firstly: *Can the German small-scale SUWM projects be defined as micro-transitions and what is the potential of SUWM for upscaling and evolving into or contributing to an urban water management transition?*; the next: *What are the impeding and supporting conditions to an implementation of SUWM as defined within the research on the cases in Germany?* is thoroughly discussed as it is a principle input to the primary research-question; following is: *What of the found conditions can be transferred to areas with established (water) infrastructure?*; and last, leading towards the conclusion is: *What are the implications of the found impeding and supporting conditions in implementing SUWM for planning practice and policy in order to upscale SUWM and to what degree is an upscaling of SUWM desirable or beneficial?*

4.1. Water in Germany – Resources and Urban Management: The Research Context

Hillenbrand et al. (2013) describe Germany as rather richly equipped with water resources and efficient water management. Yet, Germany will be affected by changing precipitation patterns and increasing temperatures induced by climate change. This is likely to result in a reduced drinking water availability (Hillenbrand et al., 2013). An already existing problem is the modification of water bodies that exacerbate extreme rain events into serious flood incidences. The EEA (2008) identifies Germany as a country facing water stress due to the high demand of cooling water for thermal power stations (Umweltbundesamt, 2014).

Germany derives all its water from either groundwater or surface water (Hillenbrand et al., 2013) which reflects both the consumption of natural water sources as well as the dependency on a favourable future condition of these water bodies (see Section 1.1.). Whether the favourable conditions sustain, remains unclear because of climate change and the current usage of water.

Over the past two and a half decades the domestic use of water in Germany has declined. This had a negative side impact on the installed infrastructure that was built for larger amounts of water in various locations in Germany (Hillenbrand et al., 2013). The decreased usage of water resulted in an inconsistent flush through the pipelines, leading to defilement and

problems in sewage treatment that did not receive sufficient replenishment (Londong et al., 2011). This is an example of the discordance of the current system and changing user habits, and thus of the close relation between technology and humans (see Section 1.1.). Such situation asks for creative innovations concerning water-carrying infrastructure that prove to be more flexible towards change (Hillenbrand et al., 2013) as discussed within this thesis.
This context of the usage of and dependence on water bodies and complications with the current water infrastructure provides a good starting point for locating the cases that are analysed in this study as they indicate the possibility of alternative approaches and thus serve as good precondition for proceeding towards a new approach.

Germany is advanced concerning the implementation of SUWM compared to other countries (Green, 2011). For instance, green roofs are much more common in Germany compared to e.g. England or France, resulting from its governmental federal structure that leaves much responsibility to the local levels (Green and Anton, 2012). In this diversity, innovation spreads more quickly as the individual local levels are faster in adapting innovation. Additionally, a clear legislation exits on water issues (Green and Anton, 2012), meaning that distinct regulations exist for urban water management.
Germany was early in researching and implementing sustainable stormwater management (Hoyer et al., 2011). Moreover, the German government has recognized the problem of urban water infrastructure and is asking for alternatives: 'In order to adapt to the changing conditions, innovative, flexible and feasible solutions are needed to secure drinking water supply, sanitation and stormwater management for the future.' (NaWaM, n.y., p.2). The German Federal Ministry of Education and Research is therefore funding various research projects in this area (NaWaM, n.y.).

The German water industry recognized the requirement of integrating environmental concerns and flood protection into water management. It claims key challenges to the water sector are: the reduced use of water by consumers, demographic change and climate change (ATT, BDEW, DBVW, DVGW, DWA and VKU, 2015). The decreasing demand of water is inverse to the worldwide predicted increase of demand due to population growth (van Meene et al. 2011). In Germany, per capita water demand is decreasing (ATT, BDEW, DBVW, DVGW, DWA and VKU, 2015) and the population is not growing (Hummel and Lux, 2007). In some areas, cities are even shrinking which puts pressure on the existing water infrastructure system designed for higher demand (Naumann and Bernt, 2009).

Germany is following the linear approach of water management (see Section 1.1. and Figure 4) with drinking water production, preparation, storage, transport and finally consumption for the various uses (Ott et al., 2016). In some areas, water is transported rather far within a long-distance water supply system (Waidmann, 2015). The treatment is likewise centrally organized with no differentiation regarding the degree of contamination. Discharge happens either together with or separated from rainwater (Ott et al., 2016). Almost 97% of the German population is connected to the public wastewater treatment stations (OECD, 2017). This current situation of water management is significant to keep in mind when deliberating on a transition in the German urban water management.

The drinking water supply as well as the disposal of wastewater are public responsibilities that have to be carried out by the municipalities (Schramm et al., 2017). But not all services are ultimately provided by the municipalities. Diverse forms of privatization and partial privatization exist in the German water supply sector, making it a rather complex sector. However, there is a discussion about the appropriateness of a private water supply (see for instance Scheele et al., 2008; Trapp and Libbe, 2016) and a trend to a reacquisition through the municipalities as for instance in Stuttgart (SWR, 2015). Zschille et al. (2010) state that the German water sector is highly fragmented with big variations in the water pricing. This variability in responsibility can make a difference regarding the implementation of SUWM or for giving policy advice as the addressee is changing accordingly.

The Water Resources Act (Wasserhaushaltsgesetz), regulating water management, is the central law in the water legislation (Hanke, 2016) and thus key to the implementation of SUWM. Since 2010, a reformed Water Resources Act is in place. It is clearer and gives more power to the state that can now directly prescribe detailed regulations and also towards individual citizens, whereas before the Bundesländer (federal states) were intermediaries (BMUB, 2017).

The Water Resources Act claims as its core aim sustainable water management, recognizing water as a part of nature and protecting it as usable good (WHG, 2009). Next to protecting ecosystems and water as a public good, it names the prevention of impacts as a result of climate change and floods as a priority. When possible, water shall be taken from nearby sources. It needs to meet hygienic standards and preparation and treatment facilities must comply to certain technological rules. Wastewater legally contains both used and rainwater

and needs to be discharged conforming to defined rules. Regarding disposal, it is explicitly mentioned that it can succeed as such in decentral facilities as long as not harming the common welfare (WHG, 2009). Thus, the Water Resources Act both addresses environmental sustainability and climate change adaptation and provides the basic legislative framework for the implementation of SUWM.

4.2. Deviation from the Conventional: Presentation of the Cases

In this section, the five cases of Hamburg, Stuttgart, Knittlingen, Frankfurt and Hannover, are presented. In Table 5 background information about the cities and the water sectors are collected. The table shows that the context of the cases differ which is the explained approach of this comparative research (see Chapter 3). The dependency on surface and/or groundwater bodies is disclosed. The responsible water supplier and disposer, from here on referred to as water utilities are displayed as they are major stakeholder in the urban water sector. The regular situation in each city is that these water utilities centrally supply inhabitants with water from the indicated sources and dispose wastewater to central treatment stations. Rainwater is either included in the system or going into a separate system. Each case deviates from this conventional situation in ways explained in the following sections.
After the case presentation, the results of the interview and document analysis are displayed.

	Hamburg	Stuttgart	Knittlingen	Frankfurt	Hannover
Status and location	City state in Northern Germany (bpb, 2013)	State capital of Baden-Württemberg (Stuttgart, 2017a)	Town in Baden-Württemberg (Knittlingen, 2017a)	City in Hesse (bpb, n.y.)	State capital of Lower Saxony (bpb, 2013)
Inhabitants (in year)	1.800.00 (2015) (Statistik Nord, 2016)	610.000 (2017) (Stuttgart, 2017b)	8.000 (2017) (Knittlingen, 2017a)	730.000 (2016) (Stadt Frankfurt am Main, n.y.)	550.000 (2016) (Hannover, 2016)
Structure of water supply and treatment	Water supply and disposal by public company Hamburg Wasser (a horizontal group consisting of two companies: the water works and the drainage company (Hamburg Wasser, n.y.a)	Drainage system, including the discharge and treatment of wastewater, in municipal hands (Stuttgart, 2017c) Drinking water supply organized by the company Netze BW, a subsidiary of EnBW (EnBW, 2017) Delivery of water arranged by two municipal administration units, EnBW has a share of 30% in each of the administration units to ensure access to water (EnBW, 2017).	Water supply by the waterworks of Knittlingen Wastewater collection and treatment by associations (AV Weissach, n.y.; Knittlingen, 2017b)	Water supply by mainova AG which is in public hands (Mainova AG 2017a; Mainova AG 2017b) Water delivered by Hessen Wasser Disposal of water by public drainage company (Stadtentwässerung Frankfurt am Main, n.y.)	Water supply by public utility (Hannover, n.y.a), an administration unit and the private company Harzwasserwerke (WVN, 2017; Harzwasserwerke, n.y.) The city drainage is organized by the public drainage company (Hannover, n.y.b)
Source of water	Water stems from groundwater in and around Hamburg and is discharged into the Elbe (Hamburg Wasser, n.y.b ; Hamburger Wasserwerke GmbH, n.y.)	Lake Constance Danube Catchment Area Stuttgart is dependent on long-distance water supply	20% Lake Constance, 80% groundwater (Knittlingen 2017b; Interviewee 8_Knittlingen_2017)	Ground and spring water (Hessenwasser GmbH & Co. KG, n.y.)	Mostly groundwater, some from springs or dams (Hannover, 2017)
Type of canalization (rainwater separate or all mixed)	About one quarter of the canalization is a mixed canalization, the rest is a separate system (Hamburg Wasser, n.y.c)	Traditionally a mixed sewage system (Interviewee_6_Stuttgart)	The district Knittlingen belongs to, mainly has a mixed canalization (Büringer, 2015)	About one quarter of the system is a separate canalization, the rest is a mixed canalization (Frankfurt-Greencity, n.y.)	Mostly separate system, only in few parts of the city a mixed canalization (Hannover, n.y.c)

Table 5: Background information about the five cases (author, 2017).

Jenfelder Au, Hamburg

The quarter analysed for this research is the Jenfelder Au, a former barracks area, measuring 35 ha that is designed for more than 2000 residents and located at the district Wandsbek (LIG, n.y.). There was an urban design competition in 2006 which was won by a Dutch urban design and landscape architecture bureau. In 2011, the first construction areas were tendered to joint building ventures and investors (ZEBAU, 2012). The entire development is to be finished by 2020 (LIG, n.y.).

In this quarter, Hamburg Wasser implements a concept called HAMBURG WATER Cycle (HWC) (see Figure 9). HWC bears the key component of separating and dealing differently with rainwater, greywater and blackwater, thereby combining the sectors water and energy as energy is generated locally through the blackwater (Hamburg Wasser, 2017). To achieve a high energetic potential, a vacuum system is installed for the toilets, which requires only 0,8-1,2 litres of water per flush and thus leads to a high concentration of biomass in the blackwater. Through anaerobic treatment, the blackwater is turned into biogas which is then converted into electricity and thermal energy (ZEBAU, 2012). The greywater is treated locally before being discharged into local waterbodies. The rainwater either drains or evaporates via green areas or is directed into ditches and retention basins (Hamburg Wasser, 2017).

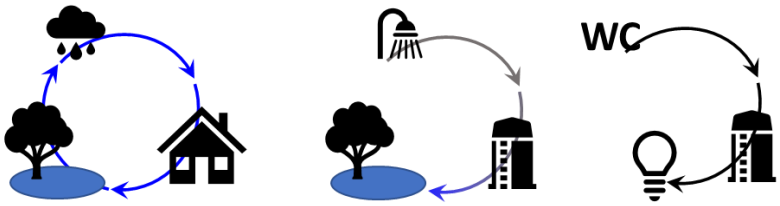

Figure 9: Principle of the Hamburg Water Cycle, from left to right: Rainwater, greywater and blackwater (modified after Hamburg Wasser, 2017).

Aim of the project is to combine an area-based climate protection concept with HWC at its centre with urban design (Nationale Stadtentwicklungspolitik, 2013). The district experiences an upgrading through the project Jenfelder Au (Glitz, 2016).

The concept HWC is accompanied by the research association project KREIS (see Figure 10). There have been preparatory investigations in the planning and construction phase and the operation is monitored. Findings and experiences are collected for application at the Jenfelder Au but also for transfer to other projects, both nationally and internationally (Hamburg Wasser, 2015).

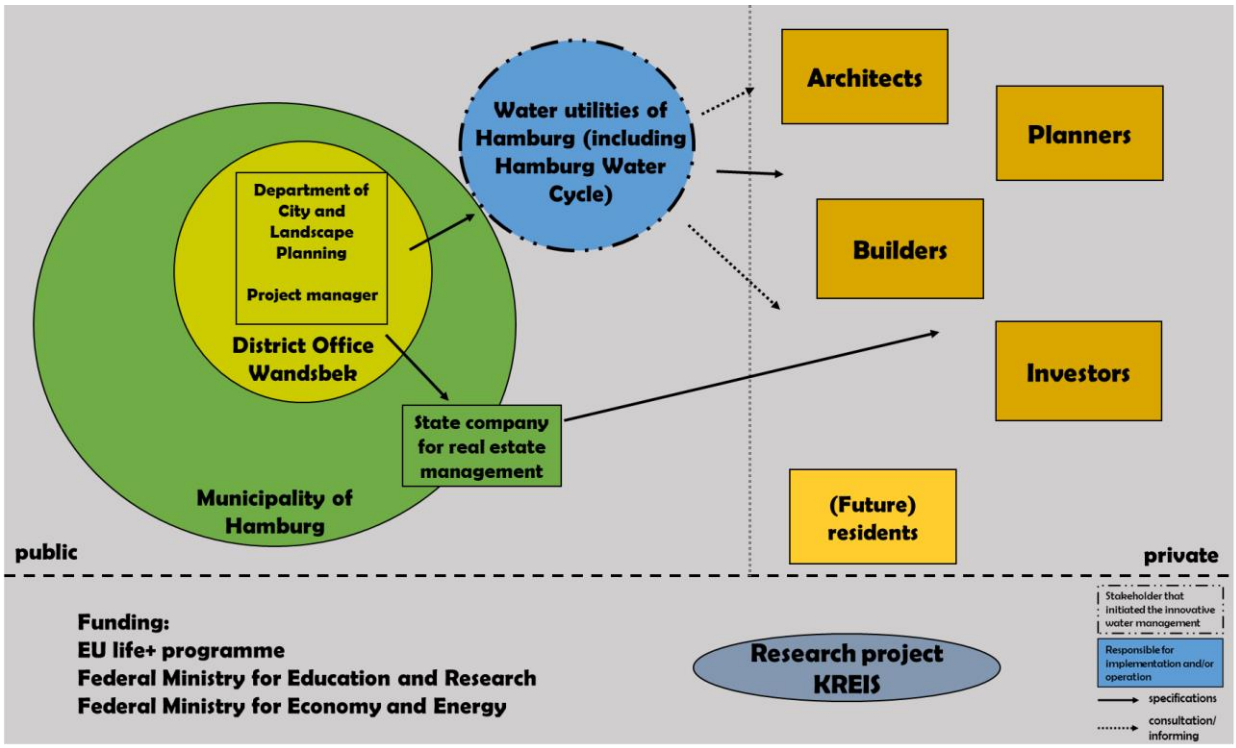

Figure 10: Chart on actor constellation of Hamburg: the stakeholders with connections to each other as named in documents and interviews. Only emphasized connections are indicated. Self-evident interaction or regular get-together among all stakeholder are not indicated (author, 2017).

Hohlgrabenäcker, Stuttgart

Hohlgrabenäcker is a new development located in the district Zuffenhausen and placed on a slope. The area consists of 18 ha and was planned for around 1200 inhabitants. Due to geological circumstances, it is impossible to install an underground infiltration system. The slope constrains a superficial rainwater infiltration. Therefore, retention (see Figure 11) has been selected as the best solution (Diem, 2006).

The development was planned from 2003-2007 and construction started in 2007 (Hoyer et al., 2011). The construction, including the housing, was finalized in 2016 (Interviewee_4_Stuttgart). The Civil Engineering Department demanded a decelerated disposal of rainwater into the local receiving water body (Referat Städtebau, 2003).

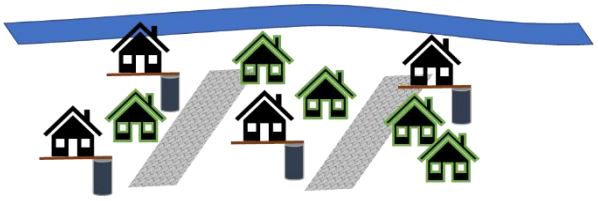

Figure 11: A combination of green roofs, cisterns and permeable streets with excess water going to a nearby receiving water (author, 2017).

Retention is achieved through a combination of three different measures. These measures are cisterns, green roofs and permeable paving stones. Thus, sealing is reduced and there is no high demand put on the sewage system (Ansel, 2013). The cisterns were prescribed at those properties that do not have a green roof (Interviewee_4_Stuttgart). The water collected in the cisterns can be used as process water (Diem, 2006). It is known that some residents use the water from the cisterns for instance for irrigation or toilet flushing (Interviewee_5_Stuttgart) but there is no precise overview on the usage (Interviewee_6_Stuttgart). The permeable paving stones have been constructed before the housing development started. The absorbability of such a street spared the construction of a separate retention basin (Auner and Diem, n.y.).

The municipality assigned the development to a private urban development Ltd. (Interviewee_5_Stuttgart), and determined specifications concerning the drainage (Interviewee_4_Stuttgart) (see Figure 12). An engineering bureau was commissioned with the planning of the site development and thus the drainage of the area (Interviewee_4_Stuttgart).

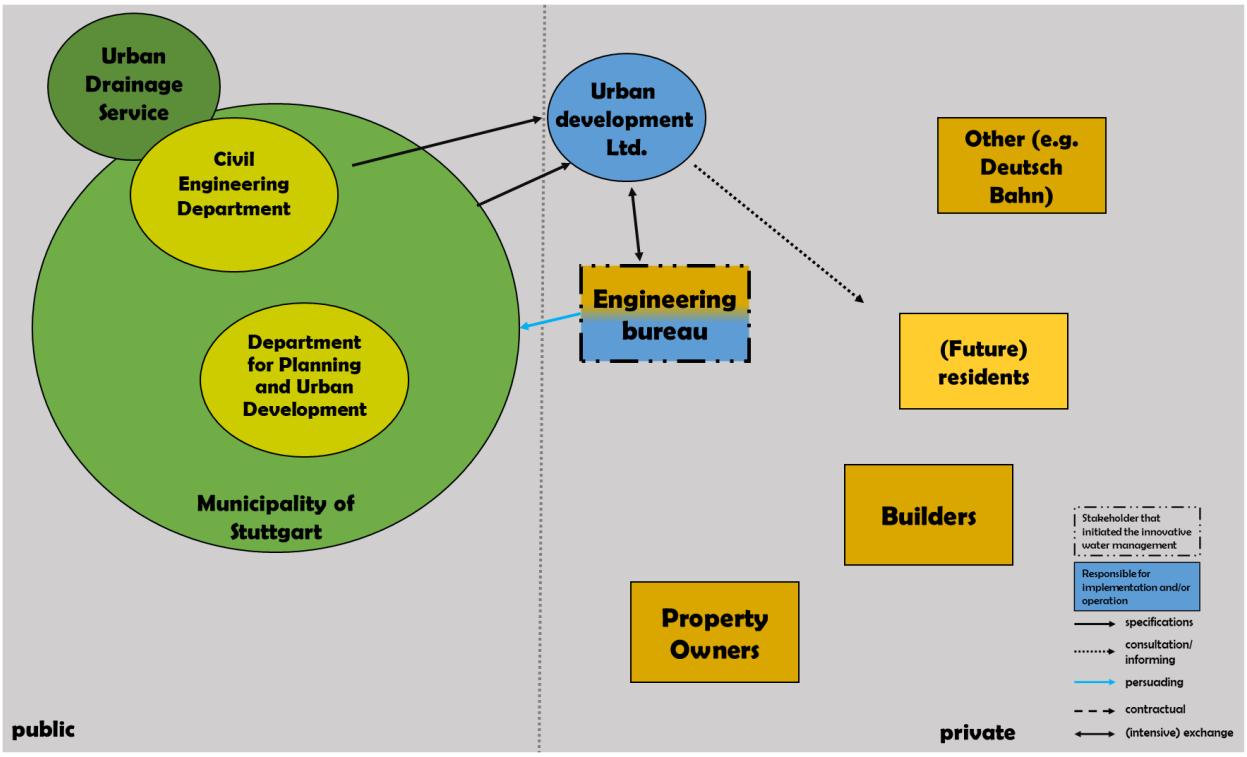

Figure 12: Chart on actor constellation of Stuttgart: the stakeholders with connections to each other as named in documents and interviews. Only emphasized connections are indicated. Self-evident interaction or regular get-together among all stakeholder are not indicated (author, 2017).

DEUS 21, Knittlingen

In Knittlingen, the concept and project DEUS 21 was implemented in the course of the new development of a residential area (DEUS 21, n.y.a). The concept (see Figure 13) contains different components: The collection and treatment of rainwater for reuse, the collection of wastewater through a vacuum system and including an energy generation and recovery of substances (DEUS 21, n.y.b). The research project ran from 2006-2010 and the vacuum station has been running since 2005 (Fraunhofer IGB, n.y.).

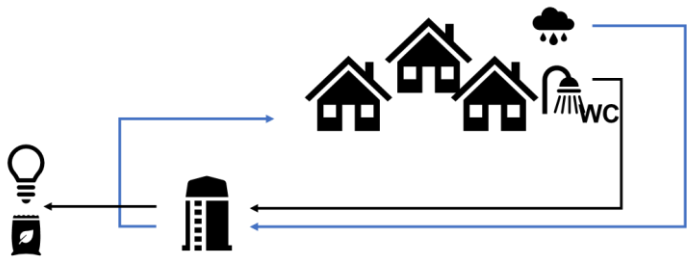

Figure 13: Concept of DEUS 21 (modified after DEUS 21, n.y.b).

Trösch (2006) describes the original concept in more detail: Rainwater is collected separately from other water and stored in cisterns before being treated up to drinking water quality. Afterwards it is directed to the houses via an additional supply line. The vacuum system for the wastewater contains collection chambers that are placed next to the houses, meaning that in the houses conventional toilets are installed unless decided differently by the builders. Furthermore, builders can decide to construct a crusher for kitchen waste that would then go along with the wastewater. By means of an anaerobic treatment, biogas is generated and can be used as renewable energy and nitrate and phosphor is extracted and can be used as fertilizer. The treatment plant is part of the so-called water-house located in the residential area. Next to the treatment of wastewater, the water-house contains the treatment and distribution of the rainwater and the vacuum station.

DEUS 21 is a research project and its implementation in Knittlingen serves as a demonstration (Fraunhofer IGB, n.y.). The IGB was responsible for planning, construction and operation (DEUS 21, n.y.a) as well as the coordination of the project (Interviewee_7_Knittlingen) (see Figure 14). The Fraunhofer Institute for Systems and Innovation Research Karlsruhe conducted research for instance on socio-economic matters (DEUS 21, n.y.a) and dealt with communication and assessment of the project (Interviewee_7_Knittlingen). The municipality of Knitllingen provided the area for the implementation and agreed to the project. The water works take part in the operation (Interviewee_8_Knittlingen).

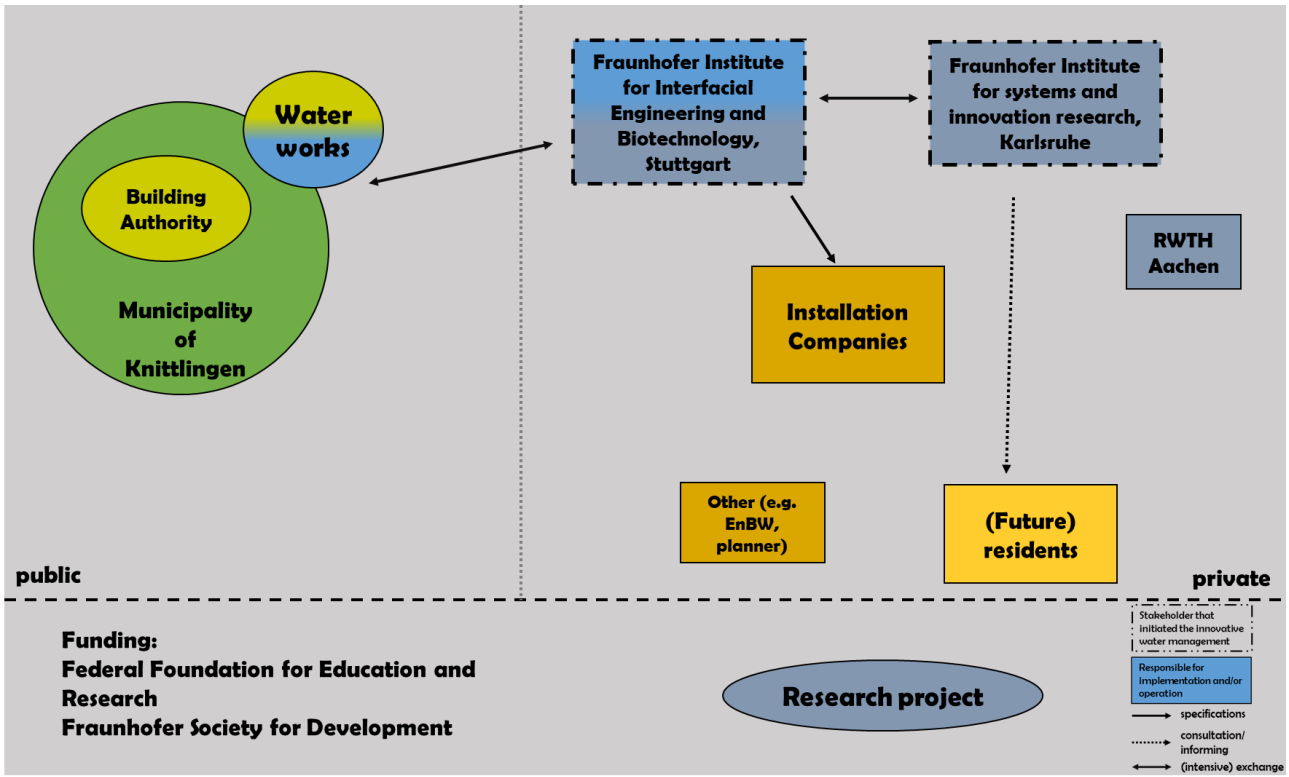

Figure 14: Chart on actor constellation of Knittlingen: the stakeholders with connections to each other as named in documents and interviews. Only emphasized connections are indicated. Self-evident interaction or regular get-together among all stakeholder are not indicated (author, 2017).

Frankfurt

The case of Frankfurt is a passive house that has been built in the district Bockenheim with 70 apartments and a day care centre. Two innovative water management elements are included in the house (see Figure 15): The production of heat from wastewater and the recycling of greywater that is reused for toilet flushing. Construction started in 2014 (ISOE, 2014). In 2016, the operation started (Deutsches Institut für Urbanistik gGmbH, 2016).

Figure 15: Concept of the system in Frankfurt: Generation of heating and greywater recycling for flushing-reuse (author, 2017).

In the area of the day care greywater and blackwater is distinct. Both is used for heat recovery but the greywater is recycled and used for toilet flushing. Wastewater from the apartment is collected jointly and used for heat recovery but without reuse. Instead, it is going directly to the public treatment plants (ABGnova, 2014). As the implementation happened in-house,

there is no need for coordination with owners of the sewers and no heat is lost on the way to the sewers (ISOE, 2014). The implementation of this water infrastructure is a field test and part of the research project netWORKS3 (ABGnova, 2014). Apart from the water-related aspects, the achieved heat recovery contributes to the energy-efficiency of the already energy-efficient passive house (ISOE, 2014). The responsibility for implementation lays with the ABG Frankfurt Holding, the housing association of the municipality of Frankfurt (ABG Frankfurt Holding GmbH, 2017), and the ABGnova (netWORKS, 2016). There are various other project partners from practice (see Figure 16). The Institute for Socio-Ecological Research (ISOE) is the coordinating partner (ISOE, 2014). The ABG Frankfurt Holding GmbH (2014) describes the implementation in the passive house as a test for future implementations as the heat recovery is supposed to become a standard at another project.
As the implementation happened within one building, the system only concerns private space (Interviewee_9_Frankfurt).

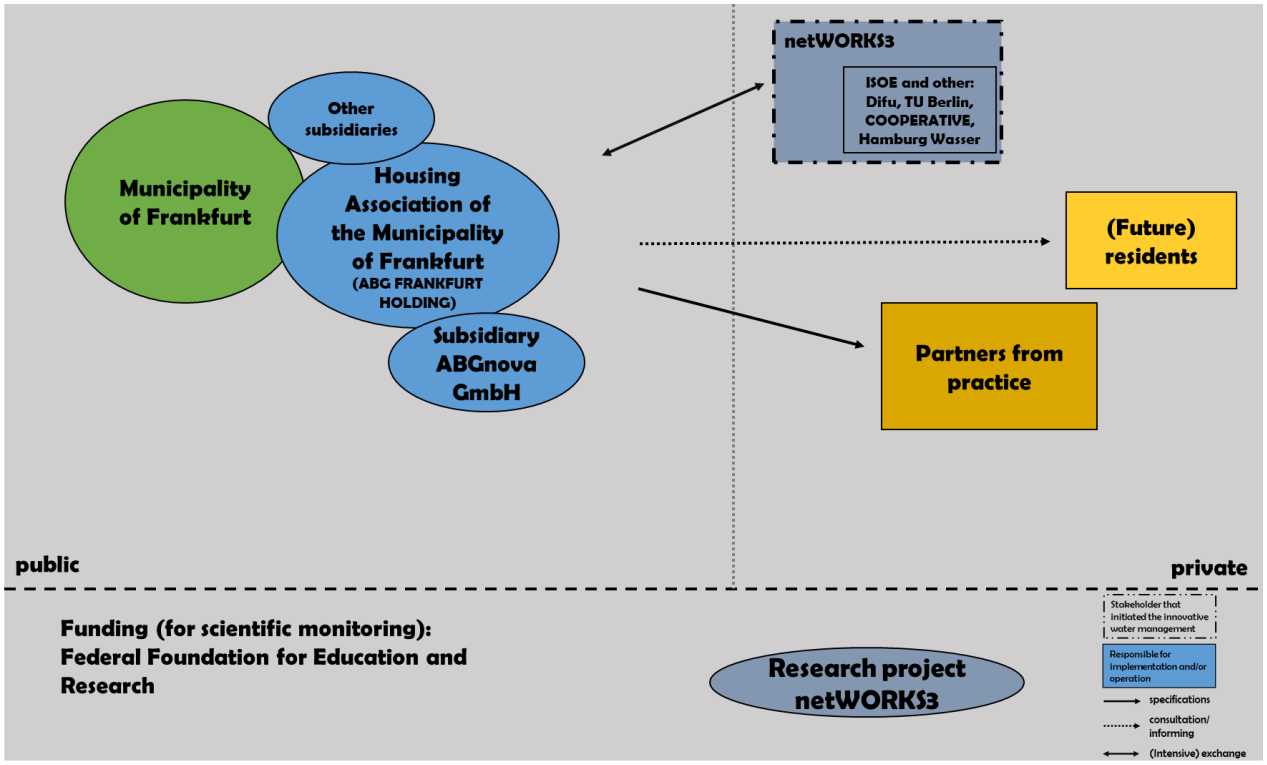

Figure 16: Chart on actor constellation of Frankfurt: the stakeholders with connections to each other as named in documents and interviews. Only emphasized connections are indicated. Self-evident interaction or regular get-together among all stakeholder are not indicated (author, 2017).

Öko-Technik-Park, Hannover

The examined case is located in the district Sahlkamp and called Öko-Technik-Park Hannover. This park was introduced already in 1995 with the purpose of testing new

technologies in the water and solar sector (Öko-Technik-Park, n.y., see Figure 17). Techniques were added over several years (Öko-Technik-Park, 2001). Some of them are installed and in operation until today whereas others have been shut down (Interviewee_10_Hannover). This case sheds light on earlier conditions and thus, enables the inclusion of the factor time.

The Öko-Technik-Park consists of a residential area, buildings of a church community, a district farm and a primary school (Öko-Technik-Park, n.y.). The implementation has happened either in existing buildings, e.g. the residential houses that were renovated, or in newly constructed buildings, e.g. the district farm (Öko-Technik-Park Hannover, 2001; Interviewee_11_Hannover).

Figure 17: Various techniques implemented, with a focus on awareness rising (author, 2017).

The drainage company of Hannover commenced the project (see Figure 18). A real estate company owns the residential houses (Öko-Technik-Park, n.y.) and was the first to be included (Deutsche Gesellschaft für Technische Zusammenarbeit GmbH, 2005). Apart from the other property owners (church community, district farm, primary school), an engineering bureau is a project partner and attends the public relations. Next to testing various techniques, a main intention was to raise awareness of environmental aspects to the public (Öko-Technik-Park, n.y.). Implemented techniques are for instance vacuum toilets, urinals without water for rinsing or greywater facilities based on a reed bed (Öko-Technik-Park, 2001).

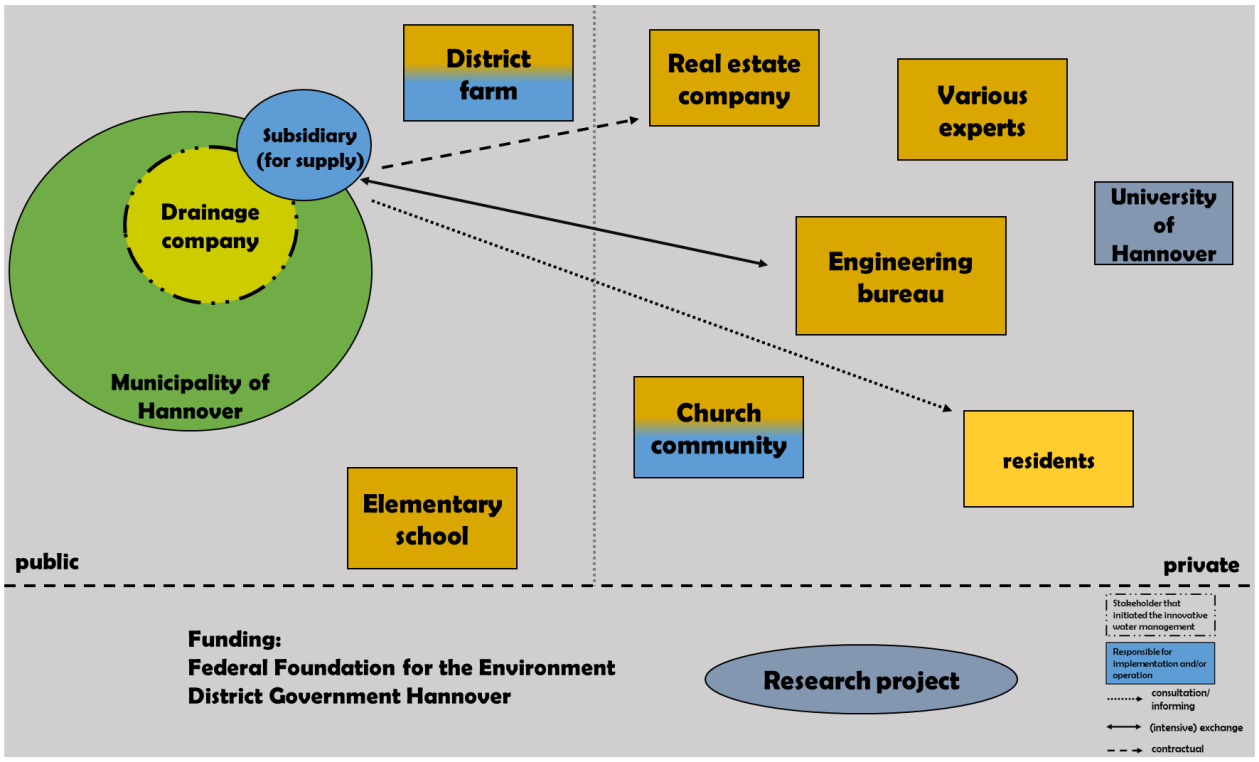

Figure 18: Chart on actor constellation of Hannover: the stakeholders with connections to each other as named in documents and interviews. Only emphasized connections are indicated. Self-evident interaction or regular get-together among all stakeholder are not indicated. However, in this project the different stakeholder stood rather apart (author, 2017).

4.3. Conditions, Role and Implications of SUWM in Germany: Findings and their Discussion

The first part of this section contains the conclusions drawn from comparing the cases. This is followed by a second part on which of these findings can be transferred to an implementation in existing structures. Following, there is a part on transition-related aspects to help understanding the role of SUWM in Germany. And last, recommendations to policy and planning are given based on the beforehand discussion.

4.3.1. Impeding and Supporting Conditions to the Implementation of SUWM in Germany

In this section, the sub-question '*What are the impeding and supporting conditions to an implementation of SUWM as defined within the research on the cases in Germany?'* is answered. 'Impeding' and 'supporting' do not mean that the condition has been a huge barrier to the project or that the project would not have been possible without that support. Instead, the terms describe any negative or positive influence that might have been easy to overcome

or describe a helpful facet. Impeding can also be an aspect that prevented a higher performance of the project but did not interfere with the entire project.

Factors, as for instance laws or legislative norms, that are mentioned as impeding condition can at the same time be named as supporting condition. Depending on their form, they can have opposing functions. Impeding and supporting conditions are furthermore related because supporting conditions can be equivalent to the tool needed to overcome an impeding condition.

IMPEDING CONDITIONS

Legal Framework

The legal framework has affected three cases (Hamburg, Stuttgart, Knittlingen). In Hamburg, it concerned the entire project: '*the wastewater acts, they currently always presume a, for the wastewater, a single line system. And the Wastewater Act had to be changed to that effect that a second wastewater line […] is in place*' (Interviewee_2_Hamburg); whereas in Stuttgart and Knittlingen only a higher performance of the project was prevented. Interviewee_4_Stuttgart explains: '[*W]hat we could not enforce at that time, that is the rainwater usage*' and '*but meanwhile, the norms for rainwater usage are developed and it is regulated more precisely, what you are allowed to use rainwater for*'. In Knittlingen, the problem was related to cost-efficiency as it was possible to achieve the standards for drinking water quality which '*works technically, but the whole issue is far away from an economic feasibility*' (Interviewee_7_Knittlingen).

Thus, a legal impediment can be found to some extent but is not a strong barrier. The legal framework has rather been encountered as a potential supporting condition (see next section). In literature, the legal framework had been emphasized as obstacle more strongly (for instance Brown and Farrelly, 2009; Kluge et al., 2012).

In principal, the Water Resources Act allows for the implementation of novel sanitation systems as it allows for decentral solutions (DWA, 2014; see Section 4.1.2.). Yet, uncertainties exist in the handling of the products (e.g. treated water or fertilizer). Furthermore, it is compulsory for every property to connect to the sewage system. Exceptions exist only for individual solutions (DWA, 2014) which suggests that individual projects as analysed here do not experience the same legal obstacles as a larger implementation would.

Human Institution

Impeding aspects relating to a human dimension have been alluded to in almost every case. Scepticism or uncertainties, stemming from either future residents or the municipality was mentioned: '*[I]t became clear that, because of the installation of these novel toilets, these vacuum toilets, substantial uncertainties were present. That is, uncertainties by later house buyers, or rather residents, by the housing companies, by the architects, by the technical building services prevailed*' (Interviewe_2_Hamburg). Further, Interviewee_4_Stuttgart describes how the novel permeable street that was implemented is perceived sceptically: '*So, the concerns are still very high and large and then one has to reason a lot and show persuasive efforts*'. Interviewee_1_Hamburg describes that '*[t]he technique has stayed for decades, the sanitary companies know that and they know what to build, and they build standard-conforming and based on state-of-the-art and all that*' which can be interpreted as an agreement on how to build and thus an institution (Hodgson, 2006). SUWM is now deviating from this institutionalized practice and as such receiving scepticism. Institutional path-dependency has likewise been recognized as a hindrance in the literature-based Section 2.2.2.. Bos and Brown (2012) see institutional inertia as major obstacle for a transition.

Missing Cost-Efficiency

In two cases (Knittlingen and Hannover), missing cost-efficiency of the projects was explicitly mentioned. In two other cases (Hamburg and Frankfurt), a proper evaluation has not yet been conducted and only for Stuttgart, Interviewee_4_Stuttgart claimed that '*[a]ll in all, […] we could prove that this decentral system is cheaper*'. However, this is the only case where the main focus is on rainwater management and not the reuse of wastewater (for energy or water itself). Context becomes important as: firstly, cost-efficiency depends on the size of the installed infrastructure: '[*I]t starts somewhere at 5000 inhabitants, that it could pay off to operate such a system self-sufficiently*' (Interviewee_7_Knittlingen); secondly, if sufficient drinking water is available: '*[F]ar away from an economic feasibility […], given that there is sufficient drinking water*' (Interviewee_7_Knittlingen); thirdly, if money is saved because other, conventional infrastructure does not need to be built and operated anymore: '*[O]nly through operation cost, there is not sufficient power behind, one can only do that, when infrastructure can be saved*' (Interviewee_11_Hannover); and fourthly, if a renovation or new development is planned in any event: '*[T]hey had to be renovated from the ground up anyway and that means, there have hardly been any additional costs*' (Interviewee_11_Hannover).

Relating back to the social dimension, Interviewee_11_Hannover states that on behalf of the water utilities in Hannover, it was only looked at cost-efficiency and '*there simply lacked the idealism*' to continue to be involved without cost-efficiency.

As described in Section 2.2.2., Schramm et al. (2017) identify an uncertainty concerning costs as well as Ott et al. (2016), who describe the high expenses of implementing a new system as an obstacle. These statements support the finding that the financial dimension in terms of cost-efficiency or the uncertainty about it can be an impediment.

Missing Communication Structure

An important condition to the implementation of SUWM as identified within this thesis is the existence of a communication structure between acting stakeholders and the municipality. In two cases, it was explained that means of communication first had to be found (Stuttgart and Knittlingen). Interviewee_5_Stuttgart describes that '*[t]hen one does have to get everyone around one table and to then make decisions, that is not very easy*' and '*it worked well and once you have a contact person, then it is fine*'. The other way around, this means that to establish a working communication structure not only between stakeholders and the municipality, but among all actors can be supporting (as is the case in Hamburg) and is discussed in the section on supporting conditions.

Unfamiliar Technique

Obstacles related more directly to the new infrastructure are also found. As described above, there is scepticism towards the unknown. But problems arise also more practice-related as '*there are no, neither companies nor planners, that have intensively engaged in this*' (Interviewee_1_Hamburg). In Frankfurt, the challenge was faced that '*this company, that would deliver everything* [*author`s note*: the different techniques], *that was not existent*' (Interviewee_9_Frankfurt), which then led to extra effort of reorienting the tendering.

In Öko-Technik-Park (2001), it is described that the techniques require more effort concerning maintenance and operation. Furthermore, users have to adapt to them. For Knittlingen and Hannover problems due to inaccurate user behaviour have been described. For instance, Interviewee_8_Knittlingen explains: '*Well, there, were problems at individual houses. But that was because items had been thrown into the toilet*'.

Van Vliet and Stein (2004) confirm that new wastewater systems are accompanied by new demands towards the user who has to change his or her habit.

Competition

Two interviewees (Interviewee_2_Hamburg and Interviewee_4_Stuttgart) comment on the reuse of wastewater or usage of rainwater in general, indicating that competition of water companies can be an obstacle as they would sell less of their water and, for instance, defame greywater facilities.

Other Aspects

It is only normal that challenges arise with the implementation of a new system as pointed out by Interviewee_9_Frankfurt: '*There were problems again and again, well, it is only logical, well, this is nothing you can buy off the peg*'. Interviewee_3_Hamburg takes a similar perspective by stating: '*[W]ell this new system naturally carries new demands*'.

There is a further aspect that is not necessarily impeding but brings change and is important to consider when implementing novel water infrastructure: technology enters the private sphere leading to changing or uncertain responsibilities and roles of (public) water utilities and the private domain. This is the case for instance in Knittlingen or Hamburg. In the latter, the water utilities crossed the border into the private realm as they '*received a completely different role as they suddenly had to become active in the private realm […] the role of utilities suddenly changes*' (Interviewee_2_Hamburg). In Stuttgart, the cisterns are under private responsibility and it is unknown to the municipality who uses the rainwater and who does not. Van Vliet and Stein (2004) refer to 'a new division of responsibilities between consumers and the network of providers' (p.357) and thus underline that there is a change of responsibilities and actors have to define their new roles and orient themselves.

SUPPORTING CONDITIONS

Legal Framework

As indicated above, the legal framework has been identified rather as a supporting than impeding condition. Especially concerning rainwater (highlighted in Hamburg and Stuttgart), it is common and anchored in law to aim at a decentral management accompanied by local evaporation and infiltration. Interviewee_6_Stuttgart explains that there has been an increase in decentral rainwater management approaches '*as it has an effect on the fees*'. This statement shows that it is a well-working incentive to calculate the fees by the amount of wastewater draining off into the central sewage system and thus by the percentage of sealing on a

property. According to Agrawal and Lemos (2007) incentive-based mechanisms are a frequently used tool when governing the environment. It is described that with such incentives, the decision (on for instance the degree of sealing on one`s property) is shifted to individuals or single households and their actions 'that environmental decisionmakers seek to influence' (Agrawal and Lemos, 2007, p.40). Regarding the rainwater fee, such pattern is found here as property owners or developers decide themselves on their sealing.

In Hamburg, indeed, the Hamburg Wastewater Act had to be changed but it was possible and not more of a hurdle than any other change of law (apart from a simultaneous change of the federal Water Resources Act which prolonged the Hamburg amendment). Interviewee_1_Hamburg states '*one has to invest some years of work in this, but resistance [was] not really there, no*'. With that settled, all regulations are contained in the Wastewater Act and no special permit is required just as in no other case apart from Hannover.

Jacobsson and Lauber (2006), when discussing the diffusion of solar panels in Germany, describe the importance of a proper legal framework for an innovation to be established and gain legitimacy. For the diffusion of a new technology, there is for instance an interplay between advocacy coalitions, institutional change and formation of the market. But '[a]t the heart of this process lies the battle over the regulatory framework' (Jacobsson and Lauber 2006, p.272), supporting the finding that once a proper legal framework is there, it acts supportive but to achieve such framework can be a struggle.

Advocate

Turning towards a social dimension, different supporting conditions become clear. In all cases except for Frankfurt, at least one individual as driving force, from here on called advocate, is mentioned as important for implementing such novel projects. And in all these cases, the advocate(s) were described as crucial for the implementation: '*And that was quite helpful, without him, it might have been impossible*' (Interviewee_4_Stuttgart), and: '*[T]he head of the district office […], he wanted that, he wanted that, he aligned with that project*' (Interviewee_2_Hamburg). Huitema et al. (2011) confirm that individuals can be crucial for bringing about political change.

Flood Experience

A further exemplified factor concerning rainwater is the experience with floods by residents. Interviewee_5_Stuttgart states that someone '*who maybe has experienced this himself, such a flooded basement or who lives near a water, that person is quite happy about these solutions,*

when one can see something is being done', also claiming that awareness has risen and people are prepared to pay more for such approaches. Such conclusion is contradicted by Whitmarsh (2008), who found in a study that flood victims were not more likely to take preventive actions or respond to an increasing flood risk than people unexperienced with floods. Spence et al. (2011) explain that the findings concerning an assumed different behaviour by people who have experienced a flood differ and are partly opposing.

The aim to achieve environmental sustainability and be more resource efficient can also be pointed out as a driving force (for instance: Öko-Technik-Park (n.y.); Trösch, 2006; Hamburg Wasser, 2015).

Funds

Concerning financial aspects, it has been described above that in certain contexts, SUWM can be cost-efficient or even cheaper than conventional approaches but it has to be taken into account that the more recent projects cannot be financially evaluated yet. Meanwhile, almost all cases have received funding (with Stuttgart as exception), namely mostly from the Federal Ministry for Education and Research.

Communication Structure and Frequent Communication

As indicated above, communication among all stakeholders proved to be essential. Hamburg implemented a consultation for builders, in Frankfurt the research group was in close dialogue with the executing actors and for Knittlingen, it is described that scepticism from some of the municipal staff was overcome: '*[W]hen we had talked more intensively with them, they greatly supported us*' (Interviewee_7_Knittlingen). A well-working and constant communication is also needed because of the novelty of the implemented project. An involved research group can be in the position of passing on knowledge. Extra managerial effort (which can take different shapes depending on the individual project) is a strong facilitator of the implementation of SUWM. This effort can also show prior to the actual project when considering the options. '*Well, these, these considerations […] what kind of measures I implement in an area to achieve maximum performance, well there is obviously much preliminary planning needed, and I would actually do that again*' (Interviewee_6_Stuttgart).

The importance of communication is confirmed by Pahl-Wostl et al. (2007) stating that 'complex issues and integrated management approaches cannot be tackled without taking into

account stakeholders' information and perspectives and without their collaboration' (n.p.). Here, it has additionally been found that the passing on of knowledge is important.

Reference Projects

A further managerial aspect containing a supporting facet is the possibility to refer to or build on an existing and functioning project of similar kind. In Hamburg, a preceding project is named whose evaluation has been made use of (Interviewee_2_Hamburg), which likewise accounts for the permeable street as applied in Stuttgart. While Interviewee_7_Knittlingen describes that the project in Knittlingen was a helpful reference for another project as '*this is very important, that one can just, that one demonstrates somewhere, that one can show, it works. No one wants to be the first to try*'.

Vreugdenhil et al. (2010) classify pilot projects into three types: research, management and political-entrepreneurial. In this, they confirm that in addition to testing innovations and evaluation, pilot projects can be used as an advocacy tool that aims at demonstrating and convincing.

Political Support

In four of the cases, a political dimension in form of either support or willingness to participate is depicted. Such support is of more relevance when the area to be developed is in public hands. The advocates can come from the political realm and push a project through (for instance Interviewee_2_Hamburg and Interviewee_4_Stuttgart). Interviewee_8_Knittlingen describes as one the municipalities role '*the willingness to say, yes, we give it a try*'.

The impeding and supporting conditions discussed above are summarized in Table 6.

Table 6: Impeding and supporting conditions to the implementation of SUWM in Germany as found within the case research (author, 2017).

Impeding Conditions	Supporting Conditions
Legal Framework	Legal Framework
Exiting human institution (or habit)	Advocate (an individual proponent)
Missing cost-efficiency/profitability	Funds (in connection with research project)
Missing communication structure between actors (e.g. to municipality)	Established communication structure and frequent communication
Unfamiliar technique	Reference projects
More effort concerning maintenance and operation	Experience with floods
Competition through water industry	Political support

WHAT LESSONS CAN BE TRANSFERRED TO EXISTING STRUCTURES

The analysed cases are projects that have been implemented in a new neighbourhood development. Only in Hannover, several of the individual subprojects have been implemented in existing structures (Öko-Technik-Park, n.y.). To discuss a wider implementation of SUWM, it is essential to regard the possibilities of implementations in existing structures and answer the sub-question *'What of the found conditions can be transferred to areas with established (water) infrastructure?*. Thus, it is examined to what extent conditions or findings from the here discussed cases can be transferred to existing structures.

Principally, it can be said that SUWM-projects *can* be implemented in existing structures. But obstacles (also to achieve cost-efficiency) become bigger with water and other infrastructure already existing.

The hurdles start off with property rights. To prescribe decentral rainwater management for existing structures '*would always interfere with some property rights*' (Interviewee_3_Hamburg), indicating that the border between private and public gains importance.

In addition, technical differences have to be considered. Interviewee_1_Hamburg describes that '*[o]ne would so to say have to prepare the housing stock for such separate systems* [*author`s note*: for separating black- and greywater]'. Still, it *is* possible which can be seen in the case of Hannover where the opportunity of a renovation of the buildings has been used to simultaneously install vacuum toilets or greywater recycling and '*there have actually hardly been additional costs, because only a more or less double line was needed, it was not that complicated*' (Interviewee_11_Hannover). Logically, there would have been more costs if no renovation of the buildings had been conducted. Interviewee_7_Knittlingen points to another possibility which is to include existing structures into the considerations of implementing SUWM in a new development: '*[T]hat one thinks these concepts ahead because to concentrate only on new developments, they often are too small to start something*'.

A limitation that becomes clear when looking at DWA (2014) is that a separate discharge of rainwater is required when implementing novel sanitation systems which is not the case in all places (see also Table 4).

Managerial aspects that were identified – such as a well-working communication level, regular dialogues and companies that are unfamiliar with the techniques - are likely to remain important when regarding existing structures. Likewise, the experienced scepticism or

indicated competition by water companies can be expected to have an impact since they all relate to the event that something new is implemented.
The context-dependency (as described for instance for the financial aspect) of the value of an implementation of SUWM is applying for new developments as well as existing structures. The DWA (2014) describes in detail that various factors influence the appropriateness, for instance if existing systems are reaching a limit or if there is a need for renovation.

Findings can be translated especially concerning the managerial aspects but it needs to be recognized that the existing buildings with the alongside implemented infrastructure represents a huge impediment (see also Pahl-Wostl, 2007a; Marlow et al., 2015) and opportunities exist mainly in renovations or nearby newly developed areas.

4.3.2. Urban Water Management Transition Already Pushed Over the Edge?

In this section transition-related data is discussed. This can for instance be statements referring to the past or future or factors influencing the current situation. These influences can of course also represent an impeding or supporting condition but have then not been mentioned as a case-specific condition but as a general aspect.
In this, the sub-question: *Can the German small-scale SUWM projects be defined as micro-transitions and what is the potential of SUWM for upscaling and evolving into or contributing to an urban water management transition?* is answered.

It has already been described that Germany is following a linear and central water management system with a high percentage of the population connected to it (see Section 4.1.2.).
In Section 2.3.1., a micro-transition is defined based on Brown et al. (2011) and van der Brugge et al. (2005) as development on the micro-level that deviates from the existing standard and is locally restricted.
The projects that are analysed in this thesis are pilot projects (e.g. IKZF, 2007; Hamburg Wasser, 2015; Interviewee_5_Stuttgart), mostly accompanied or even induced by research. They are limited to a certain area and deviate from standards, reinforced by Interviewee_10_Hannover describing that '*it is still a niche market and I don`t have the feeling that, that this is happening, that the awareness is going in that direction in the field of water technologies*'. Yet, a decentral rainwater management is found to be more common

than novel sanitation systems. The here analysed rainwater management project in Stuttgart is unique and novel because of the combination of three different techniques '*as often, I only have one thing*' (Interviewee_6_Stuttgart).
Thus, the definition of micro-transition is clearly fulfilled in the analysed German projects.

In Section 2.2.2., the inflexibility and longevity of the existing system connected to high expenditures (Pahl-Wostl, 2007a) is identified as an impediment. This is confirmed by for instance Interviewee_1_Hamburg: '*We in Hamburg have the misfortune as in any other larger municipality that our gold is, so-to-say, buried, it is lying there and one does not want to throw it away*' and Interviewee_2_Hamburg: '*[I]n the water management, we have very, [...] very long-lasting commodities*'. It is difficult to change this existing system especially as in Germany '*in most sectors, there are not sufficient problems*' (Interviewee_11_Hannover), meaning that it is simply not economical to implement new approaches as contained in SUWM. Interviewee_7_Knittlingen, also mentioning the inertia of the current system, explains that political action is needed for driving change as '*honestly, well, many things, especially in, in the sector of wastewater techniques have actually only then been implemented to a larger extent, when there was a legal basis*'.
The above delineated competition through the established water companies representing the meso-level or regime (so the predominant rules and practices) is acting inhibiting. Rotmans et al. (2001) declare that '[t]ypically it will seek to improve existing technologies and use strategic action to fight off a new development' (p.19) thereby assigning inhibition through the regime to the early phases of a transition.
Hence, SUWM in Germany is present in the form of micro-transition but experiencing major constraints towards a proliferation.

However, a development of the water sector can be identified. Projects learn from or build on preceding or similar projects and enhancements are realized (for instance in Hamburg). In Stuttgart, changed rainwater norms enabled an advancement concerning the prescription of rainwater usage, which was thus determined in a following project where the Interviewee_4_Stuttgart`s bureau participated. The statement '*and, as already mentioned, one can refer to these norms and then has less of this discussion*' (Interviewee_4_Stuttgart) underlines the supporting effect an appropriate legal framework can have and additional that practitioners make use of their experience for following projects.

Concerning the oldest project in Hannover (starting in 1995), it is claimed that, today the knowledge about the techniques is much further than at that point and '*[n]ow, it is really more about, how can operating models be developed for larger units, how does one line up with maintenance contracts and such*' (Interviewee_11_Hannover). Interviewee_10_Hannover describes: '*Somehow, I have the feeling we were ahead of the times*' and furthermore explains that the project was mainly possible because of the timeframe of the Expo (*author`s note:* millennium world exhibition in Hannover) where such projects were supported. Such an outer positively influencing factor has not been mentioned in any other of the, more recent, cases.
Thus, it can be stated that there is no stagnation but an evolvement concerning the implementation of SUWM in Germany and as such the potential of a continuing evolvement.

Assuming a transition is happening, with projects only occuring at a small scale and the regime taking an inhibiting effect, it can be deduced that SUWM in Germany is situated in the early phases of a transition. Van der Brugge et al. (2005) define the take-off phase (see Figure 7) as a co-aligned micro- and macro-level, meaning that political understandings and the innovative projects support and infect each other. Political support could here chiefly be found in form of funding and only for decentral rainwater management in a proper legal framework. Thus, considering that SUWM consists of more than decentral rainwater management, a take-off phase is likely not yet reached, meaning it is unclear if a transition finalizes at all (van der Brugge et al. 2005). Hegger et al. (2007) state that in the socio-technical scope a niche development rarely advances to the regime which suggest that SUWM in Germany is by no means certain to extend.

Pushing SUWM towards the take-off phase, it can be drawn on Interviewee_7_Knittlingen who believes that '*more demonstrators or pilot projects are needed, that one can see, what is actually realistically possible, what can be achieved with this system*'. This is backed up by Interviewee_4_Stuttgart stating '*it would be good, if this would spread a bit, yes, that it works*'. More demonstration projects and a spreading of their well-functioning would much facilitate further implementation that would then potentially not run as a research project but as a regular project.

Several times, the term 'courage' is named when talking about what advice could be given to other projects. For instance, Interviewee_5_Stuttgart recommends '*to be courageous, just try out new things*'. Demonstration projects as well as advocates that can convince people, can

positively influence courage. Yet, a political and legal framework that would enable the implementation of SUWM in a safe space would now be important, making special courage superfluous and likewise to align the macro- and micro-level as suggested by van der Brugge et al. (2005). The achievement of such alignment is discussed in the following chapter when talking about planning and policy recommendations.

4.3.3. Functionalizing Micro-Transitions to Persuade the Regime

In this section, it is discussed to what extent the upscaling of an implementation of SUWM is desirable in the German context and what the found conditions in the German cases implicate for planning and policy, thereby answering the research question: *What are the implications of the found impeding and supporting conditions in implementing SUWM for planning practice and policy in order to upscale SUWM and to what degree is an upscaling of SUWM desirable or beneficial?*.

Looking back at the discussed benefits of SUWM, namely environmental sustainability and climate change adaptation, and comparing them to the situation in Germany as described in Section 4.1., with for instance a dependency on sustentive water bodies and predicted changes in precipitation, it becomes clear that a more sustainable and careful usage of water that regards the safeguarding of future water, can be desired. With the research on the cases, it emerged that SUWM is combinable and often is combined with energy production and/or reuse of substances such as phosphorous, adding a further dimension and advantage to SUWM. Schramm et al. (2017) mention a hesitancy to the implementation of SUWM as it is difficult to securely estimate its cost and performance, which shows the unattractiveness of implementing SUWM. Yet, certainty on cost and performance can only be gained by learning about it, thus, by implementing SUWM.

The exact appearance of an appropriate SUWM (e.g. what kind of technique, what scale, what functions remain central, what becomes decentral) is strongly context-dependent. Hence, it cannot be predefined what type of urban water management is to be implemented. Only recommendations on how to achieve an appropriate implementation of SUWM (if at all) can be made. Likewise, it cannot be dictated to what degree SUWM or a combination with other approaches or the existing infrastructure should be achieved. Again, recommendations can only be given to the managerial or social level. In fact, Hegger et al. (2007) criticise that in

sanitation innovation, the focus is too much on technologies, when in a socio-technological system as water management, the social side plays an important role as well. Therefore, it is suggested to formulate concepts, define the (new) actors and, by assembling all actors, find integrative solutions (Hegger et al., 2007).

Likely, the most vital implication of the conditions to the implementation of SUWM is the longevity and sunk cost of the existing infrastructure. It is most vital because it has not been found within the cases but is still referred to by interviewees and literature (see Section 4.3.1.), meaning it has not been overcome since the cases represent a succeeded implementation of SUWM. A further major obstacle is the lacking cost-efficiency as established water companies can hardly be persuaded or competed against if there is no profitability.

Major drivers to the implementation of SUWM are passionate individuals as well as political support and a proper legal framework. Currently, political support requires courage by the municipality in question and a proper legal framework can only be found for decentral rainwater management. Thus, steps to upscale SUWM are attached at these points. Thereby, special attention needs to be paid to lacking profitability and the opportunities to change the existing system.

The here suggested actions are based on the proposed transition management by Loorbach (2010). An already existing part of that management is the operational activity and experimentation which can be found in the research pilot projects that were analysed in this thesis. Moreover, a reflexive activity with monitoring and evaluation can be found, at least on behalf of scholars and individual practitioners. Two further activities mentioned by Loorbach (2010) are the strategical and the tactical activity.

At the strategical level, it is required to formulate long-term visions through frontrunners in the field of SUWM stemming from different perspectives, as for instance research, technology, water utilities, planners, etc. that together discuss and develop the visions. The government`s role in this is to initiate and gather such a network. Considering the federal structure of the German state, such vision is suggested to be designed at the state`s level, signalling political support.

At the tactical level, visions are translated into more precise agendas. Regarding the different conditions within the federal states (what is the main source of water, what water companies are active, what are the specific laws, etc.), such agenda should be developed at the federal level within the responsible ministry in cooperation with the relevant stakeholders (see Table 5 for an example). Part of this agenda is to assess the opportunities that exist for a change of the existing infrastructure. For instance, it could be evaluated where it makes sense to invest in and keep existing infrastructure and where to transform to different infrastructure. Here, the field of planning becomes important as such thoughts need to become part of any new or re-development.

A concrete example could be a Water Management Assessment that has to be conducted for any development. In addition, a person responsible for a transition in urban water management can be established within larger municipalities. Research showed that a contact person serving as link between the municipality and other actors was valuable and facilitated an implementation of SUWM. In addition, intensive communication and exchange between stakeholders act supporting, meaning that an early integration is required and needs to be promoted by both policy and responsible planner. As SUWM is linked to energy and nutrients, integration would reasonably extent to these actors. Hegger et al. (2007) suggest that an early inclusion of for instance the energy and agricultural sector is vital for realizing a transition in the field of sanitation. Furthermore, the authors outline that through the integration of established actors, an innovative project becomes rooted in the regime and is thus more likely to change the regime (Hegger et al., 2007).

To address cost-efficiency or at least out rule competition, it could be drawn on market-based incentives as described by Agrawal and Lemos (2007) that could advantage the implementation of SUWM. Yet, with water being an essence of life, it can be seen critical to expose it to the market which is seen in the discussion of the appropriateness of the privatization that has partially happened in Germany (Scheele et al., 2008; Trapp and Libbe, 2016). Thus, the problem needs to be addressed by making the evaluation of SUWM a legal requirement and giving it the legislative mandate that Schramm et al. (2017) describe to be missing. This mandate can be included in the Water Resources Act and remove SUWM from the status of being an exception from the norm (see Section 4.1.2.).

Learning through reflexive activity is visible with scholars and practitioners but needs to become a purpose within the management (Pahl-Wostl, 2007a) and within the governmental level as supply and disposal of water are public responsibilities (see Section 4.1.2.).

Vreugdenhil et al. (2010) among other identify a ‘lack [of] learning’ (n.p.) as a hindrance for using pilot projects effectively and describe that a comprehensive knowledge transfer needs to be installed. The compilation and evaluation of projects could be pursued on federal and state`s level, making findings available for anyone following a SUWM approach. The findings can additionally be used for an advancement of the legislation.

Both policy and planning practice need to make it a custom to regard SUWM as an alternative to conventional water management and infrastructure in any new development or renovation. The learning from pilot projects needs to be institutionalized and established water utilities need to be included in developing agendas for a shift towards more sustainable urban water management.

5. Conclusion: Wrapping up and Leaving Inertia behind

The aim and objective of this research was to provide a scheme of impeding and supporting conditions that are important for introducing SUWM in German urban areas. Based on a discussion of the potential and desirability of an upscaling of SUWM, implications for policy and planning practice were to be proposed and have been proposed. All of this led to the main research question, which is: *What are the supporting and impeding conditions to an implementation of SUWM in the cities of Germany and what does this imply for a potential transition in urban water management?*.

The thesis contributes to policy and planning by showing that SUWM is a viable alternative to the currently followed urban water management approach and deserves more attention in daily policy and planning practice. Important conditions to the implementation of SUWM in Germany have been worked out and developed into specific steps for an application as outlined in Section 4.3.3.. Thus, knowledge gained within this research is made usable for other cities and practitioners. Such practical guidelines have been described as missing in academic literature (Werbeloff and Brown, 2011).

Furthermore, Brown et al. (2011) describe the need for an evaluation of micro-transitions towards SUWM. Such micro-transitions, in form of pilot-projects in Germany, have been assessed and compared in detail. The empirical findings were discussed, thereby considering the theory-based conditions. Hence, this thesis contributes to the discussion on SUWM and additionally links SUWM to transition theory as described by van der Brugge et al. (2005) and Rotmans et al. (2001). The found conditions to the implementation of SUWM in Germany have been operationalised into advice for policy and planning by means of the concept of transition management from Loorbach (2010).

Built on scientific literature, climate change adaptation and environmental sustainability have been described as main benefits of implementing SUWM. Yet, it is a niche approach that experiences obstacles to a wider implementation, predominantly the longevity of the existing infrastructure accompanied by an institutional inertia as water management is a socio-technological system where the technical and social dimension co-evolve. Urban developments and the aim of increasing efficiency of water usage provide an opportunity for implementing SUWM.

Various impeding and supporting conditions to the implementation of SUWM have been identified based on empirical data derived from five cases. Some conditions exert more influence than others. Major impediments are a lack of cost-efficiency and social uncertainty meaning that the applied technique is unknown to users and companies and thus creating insecurity. Major support happened through advocates and an intensive exchange between all stakeholders underlining the integrative aspect of SUWM as defined in literature (for instance Brown et al., 2011; Belmeziti et al., 2015).

From the perspective of environmental sustainability and climate change adaptation, an implementation of SUWM appears beneficial. Whether it is beneficial has to be evaluated individually for each situation (e.g. municipality or development project), since a secure and well-working water supply and disposal as well as rainwater management needs to be provided. However, due to for instance climate change or demographic change, an altered demand on the current system can be expected, highlighting the need to leave inertia behind. A transition to a more flexible urban water management where SUWM is a common alternative is worthwhile to tackle in order to face potential water stress (see Section 1.1.).

To prevent a stagnation of SUWM as a once and for all niche phenomenon, policy and planning practice are now asked to make a more sustainable urban water management a prioritized goal and include an assessment of the benefits and disadvantages of SUWM into their daily procedures. Otherwise, a transition in the urban water management sector is unlikely to complete: The existence of long-lasting infrastructure accompanied by institutional inertia are too big a barrier for relying on the micro-level to induce change. The evaluation of the discovered conditions showed that a comprehensive transition management is required to push the diffusion of SUWM forward.

6. Reflection

The research design of this study was to compare cases that differ in their context. With SUWM being a niche development, there was not a great selection of projects to choose from. When a project was too old, it was difficult to find responsible persons that were available for an interview. With a younger project, not all potential obstacles could be detected. This can refer to emerging problems or an evaluation of costs such as in Frankfurt or Hamburg.
Moreover, it was not possible for all projects to accomplish three interviews from the three predefined perspectives (municipality, project management and planning) either due to lacking response but also because the actor constellation was different than expected. Some interviewees explained to have only little time, so that the questions had to be adapted.
With various cases evaluated, less time could be spent on each case which is a possible shortcoming as a case study lives from a detailed examination and more conditions could potentially have been found with more resources on each case. Then again, it was important to look at various cases to sustain the comparison. It remains unclear if a good balance could be found between in-depth case analysis and sustaining the comparison.

Furthermore, the document analysis is based on the documents available from the internet or provided by the interviewees. Projects that aimed at and received more public attention had consequently more documents available. Thus, there is an imbalance between the amount and usefulness of documents between the cases. With respect to Frankfurt, different documents could be found but they were very similar in content and seemed to build on the same press release. Concerning Hannover, not many documents could be found, probably because the project happened long ago.

The personal research interest and enthusiasm about a presumably more environmental friendly approach as contained in SUWM was sometimes difficult to put aside, as all interviewees supported their project, thus the notion of SUWM, and hoped to spread their innovations thereby reinforcing the research interest. However, it was tried to regard SUWM realistically as an innovation that is still being tested. In the analysis, it was strictly followed the predefined path to remain neutral towards the findings.

7. Further Research

Various issues that would deserve further examination have appeared while conducting this research. There is the implementation of alternative water systems on the individual household level through the property owners, which was not regarded here but can contribute to a transition towards SUWM. Furthermore, the residents' opinion on novel sanitation systems or rainwater use has not been looked at through self-collected data but is an important aspect of a wider implementation of SUWM as residents, as the users of these systems, need to comply to it.

A further aspect deserving in-depth analysis is the extent to which lobbying associations infiltrate the political agenda as they represent a major obstacle as soon as SUWM-innovations leave the scope of a niche development.

The altered roles and responsibilities of the water utilities and private persons in the German context deserve closer attention as the functioning of a changed water infrastructure depends on their well-working collaboration and acceptance and adjustment to their new roles.

Finally, when discussing a transition in Germany, the rural area has to be included in the research as impeding and supporting conditions are not necessarily the same as in urban areas.

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Appendix A

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Appendix B

Translation of Citations

Impeding Conditions

‘[…] the wastewater acts, they currently always presume a, for the wastewater, a single line system. And the Wastewater Act had to be changed to that effect that a second wastewater line […] is in place.’

Interviewee_2, l.105ff.: ‘[…] die Abwassergesetze, die gehen derzeit immer von einem, für das Schmutzwasser, von einem Einleitungssystem an, aus. So, und das Abwassergesetz musste dahingehend geändert werden, dass `ne zweite Abwasserleitung vorhanden liegt, vorhanden ist.‘

‘[…] what we could not enforce at that time, that is the rainwater usage.’

Interviewee_4, l.366f.: ‘[…] das konnten wir da noch nicht durchsetzen, das ist die Regenwassernutzung.‘

‘[…] but meanwhile, the norms for rainwater usage are developed and, it is regulated more precisely, what you are allowed to use rainwater for.’

Interviewee_4, l. 373ff.: ‘[…] mittlerweile ist, sind aber die Normen für Regenwassernutzung auch weiterentwickelt und, ähm, und da ist es auch klar geregelt worden, wofür man das Regenwasser auch nehmen darf.‘

’[…] it works technically, but the whole issue is far away from an economic feasibility.‘

Interviewee_7, l.104f.: ‘[…] es geht technisch, ähm, aber das Ganze ist weit entfernt von einer Wirtschaftlichkeit.‘

‘[…] it became clear that, because of the installation of these novel toilets, these vacuum toilets substantial uncertainties were present. That is, uncertainties by later house buyers, or rather residents, by the housing companies, by the architects, by the technical building services prevailed’.

Interviewe_2, l.28ff.: ‘[…] klar wurde, ähm, dass äh, durch diesen Einbau von neuartigen Toiletten, von diesen Unterdrucktoiletten, erhebliche Unsicherheiten herrschten. Und zwar

Unsicherheiten herrschten bei den späteren Hauskäufern, bzw. Bewohnern, bei den Wohnungsbaugesellschaften, bei den Architekten, bei den Gebäudeausrüstern.‘

‘So, the concerns are still very high and large and then one has to reason a lot and show persuasive efforts.’
Interviewee_4, l.397f.: ‚Da sind also die Bedenken immer noch sehr hoch und groß, da muss man sehr viel argumentieren und Überzeugungsarbeit leisten.‘

‘[t]he technique has stayed for decades, the sanitary companies know that and they know what to build, and they build standard-conforming and based on state-of-the-art and all that’
Interviewee_1, l.53ff.: ‚Ähm, die Technik ist seit Jahrzehnten so geblieben, die Sanitärbetriebe wissen das und die wissen auch was sie bauen müssen, die bauen auch normgerecht und aufm Stand der Technik bezogen und sowas alles.‘

‘[a]ll in all, […] we could prove that this decentral system is cheaper’
Interviewee_4, l.314f.: ‘Und unterm Strich nur, in der Beispielrechnung konnten wir dann eben nachweisen, dass dieses dezentrale System kostengünstiger aussieht.‘

‘[…] it starts somewhere at 5000 inhabitants, that it could pay off to operate such a system self-sufficiently.’
Interviewee_7, l.71f.: ‘[…] es beginnt irgendwo ab 5000 Einwohnern, dass sich sowas lohnen könnte, so`n System autark zu betreiben.‘

‘[…] far away from an economic feasibility […] given that there is sufficient drinking water’
Interviewee_7, l.105ff.: ‘[…] weit entfernt von einer Wirtschaftlichkeit. Also schon gar nicht in dem kleinen Maßstab, aber auch nicht unter der Voraussetzung, dass es einfach dort eigentlich genug Trinkwasser gibt.‘

‘[…] only through operation cost, there is not sufficient power behind, one can only do that, when infrastructure can be saved’
Interviewee_11, l.249f.: ‘[…] also nur über Betriebskosten ist da nicht genügend Wumms hinter, sondern man kann das nur machen, wenn man Infrastruktur einspart.‘

‘[…], they had to be renovated from the ground up anyway and that means, there have hardly been any additional costs […]’.
Interviewee_11, l.57f.: ‘[…] ähm, die mussten sowieso grundsaniert werden und das heißt, da hat`s eigentlich kaum Mehrkosten gegeben […].‘

‘[…] there simply lacked the idealism […]’
Interviewee_11, l.92: ‘[…] da fehlte dann halt so der Idealismus […].‘

‘[t]hen one does have to get everyone around on table and to then make decisions, that is not very easy’
Interviewee_5, l.415f.: ‚Da muss man doch alle an einen Tisch kriegen und dass man die Entscheidungen fällt, ist dann nicht ganz so einfach.‘

‘[…] it worked well and once you have a contact person, then it is fine’
Interviewee_5, l.423f.: ‚[…] hat gut funktioniert und wenn man dann einmal einen Ansprechpartner hat, dann geht das auch.‘

‘[…] there are no, neither companies nor planners, that have intensively engaged in this’
Interviewee_1, l.55f.: ‚[…] dass es dafür kein, weder Firmen gibt, noch Planer gibt, die sich damit intensiv beschäftigt haben.‘

‘[…] this company, that would deliver everything [the different techniques, *note by author*], that was not existent […]’
Interviewee_9, l.333f.: ‚Und dieses Unternehmen, das alles in einem liefert, das hat`s nicht gegeben […]‘

‘Well, there, were problems at individual houses. But that was because items had been thrown into the toilet.’
Interviewee_8, l.129f.: ‚Also, es gab, äh, an einzelnen Häusern Probleme. Das lag dann aber dadran, dass Gegenstände in die Toilette geworfen wurden.‘

‘[t]here were problems again and again, well, it is only logical, well, this is nothing you can buy off the peg […]’
Interviewee_9, l.320f.: Es gab immer wieder Probleme, also, es ist ja auch logisch, also, das ist ja nichts, was man von der Stange kaufen kann […].

‘[…] well this new system naturally carries new demands.’
Interviewee_3, l.275f.: ‘[…]also dieses neue System bringt natürlich auch neue Anforderungen.‘

‘[…] received a completely different role as they suddenly had to become active in the private realm […] the role of utilities suddenly changes’
Interviewee_2, l.84ff.: ’[…] kam Hamburg Wasser als Versorger auch in `ne ganz andere Rolle, weil sie plötzlich im privaten Bereich tätig werden mussten […] die Rolle des Ver- und Entsorgers verändert sich plötzlich.‘

<u>Supporting Conditions</u>
‘[…] as it has an effect on the fees […]’.
Interviewee_6, l.126: ‚[…] weil das ja gebührenrelevant ist […]‘.

‘[…] one has to invest some years of work in this, but resistance [was] not really there, no’
Interviewee_1, l.229f.: ‘[…] man muss da schon ein paar Jahre Arbeit dann reinstecken, aber Widerstand eigentlich nicht, ne.‘

‘And that was quite helpful, without him, it might have been impossible.’
Interviewee_4, l.438: ‘Und das war schon sehr hilfreich, ohne den wär`s vielleicht nicht möglich gewesen.‘

‘the head of the district office […], he wanted that, he wanted that, he aligned with that project
Interviewee_2, l.117f.: ‘[…] der Bezirksamtsleiter […], der wollte das, der wollte das, der hat sich hinter das Projekt gestellt […]‘.

’[…] who maybe has experienced this himself, such a flooded basement or who lives near a water, that person is quite happy about these solutions, when one can see, something is being done.’
Interviewee_5, 244ff.: ‘Und wer das vielleicht mal selber mitgemacht hat, so einen überschwemmten Keller, äh, oder wer am Gewässer wohnt, der ist da ganz glücklich über solche Lösungen, wenn man sieht, da wird was getan.‘

‘[…] when we had talked more intensively with them, they greatly supported us’
Interviewee_7, l.283f.: ‘[…] als wir dann mit denen ein bisschen intensiver uns ausgetauscht hatten, haben die uns eigentlich super unterstützt.‘

‘Well, these, these considerations […] what kind of measures I implement in an area to achieve maximum performance, well there is obviously much preliminary planning needed, and I would actually do that again […]’.
Interviewee_6, l. 230f.: ’ Also, diese, diese Überlegung, […] was ich in einem Gebiet, ähm, an Maßnahmen mach um, um das Maximale rauszuholen, also da ist natürlich viel Vorplanung notwendig und, ähm, das würde ich eigentlich wieder so machen […].

’[…] this is very important, that one can just, that one demonstrates somewhere, that one can show, it works. No one wants to be the first to try’
Interviewee_7, l. 301ff.: ‘[…] sowas ist ganz wichtig, dass man einfach, dass man irgendwo demonstriert, dass man auch mal zeigen kann, das funktioniert, ne. Keiner will der erste sein der`s ausprobiert.‘

‘[…] the willingness to say, yes, we give it a try […]’
Interviewee_8, l.76: ’[…] die Bereitschaft einfach zu sagen, ja wir probieren das […].‘

<u>Transfer</u>
‘[…] would always interfere with some property rights […]’
Interviewee_3, l. 509f.: ‘[…] weil das würde ja immer irgendwelche Eigentumsrechte eingreifen […]‘.

‘One would so to say have to prepare the housing stock for such separate systems [*note by author*: for separating black- and greywater].’
Interviewee_1, l. 536f.: ‘Man müsste sozusagen den Wohnungsbestand erstmal vorbereiten für solche Trennsystem.‘

‘[…] there have actually hardly been additional costs, because only a more or less double line was needed, it was not that complicated’
Interviewee_11, l.58f.: ‘[…] da hat`s eigentlich kaum Mehrkosten gegeben, weil man da nur eine Verleitung mehr oder weniger doppelt brauchte, das war jetzt nicht so kompliziert.‘

‘[…] that one thinks these concepts ahead because to concentrate only on new developments, they often are too small to start something.‘
Interviewee_7, l. 315ff.: ‘[…] dass man halt dann solche Konzepte eher weiterdenkt, ähm, weil sich nur auf die Neubaugebiete zu konzentrieren, die sind oft zu klein, um irgendwo was anzufangen.‘

Transition
‘[…] it is still a niche market and I don`t have the feeling that, that this is happening, that the awareness is going in that direction in the field of water technologies.’
Interviewee_10, l.80ff.: ‘[…]ist noch ein Nischenmarkt und ich hab nicht das Gefühl, dass, dass das hier passiert, also das Bewusstsein sich dahin entwickelt im Bereich Wassertechniken.‘

‘[…] as often, I only have one thing’
Interviewee_6, l.55: ‘[…] as weil oft habe ich nur eine Sache.‘

’We in Hamburg have the misfortune as in any other larger municipality that our gold is, so-to-say, buried, it is lying there and one does not want to throw it away’
Interviewee_1, l.549ff.: ‘Wir in Hamburg haben natürlich wie alle andere großen Kommunen das Pech, dass wir unser Gold sozusagen vergraben haben, das liegt da und das will man nicht wegschmeißen.‘

‘[…] in the water management, we have very, [...] very long-lasting commodities’
Interviewee_2, l.139f.: ‘[…] wir in der Wasserwirtschaft ja sehr, […] sehr langlebige Wirtschaftsgüter haben.‘

‘[…] in most sectors, there are not sufficient problems’
Interviewee_11, l.241f.: ‘[…] und man hat auch in den meisten Bereichen nicht ausreichend Probleme.‘

‘[…], honestly, well, many things, especially in, in the sector of wastewater techniques have actually only then been implemented to a larger extent, when there was a legal basis.’
Interviewee_7, l.377ff.: ‘[…] ganz ehrlich, also, viele Sachen, ähm, grade im, im Bereich der Abwassertechnik sind eigentlich erst dann wirklich in der Breite umgesetzt worden, wenn`s eine gesetzliche Grundlage dafür gab.‘

‘[…] and, as already mentioned, one can refer to these norms and then has less of this discussion.’
Interviewee_4, l. 375f.: ’[…] und man kann wie gesagt diese Normen eben beziehen und hat dann diese Diskussion weniger.’

‘[n]ow, it is really more about, how can operating models be developed for larger units, how does one line up with maintenance contracts and such.’
Interviewee_11, l.197ff.: ‘Jetzt geht`s wirklich mehr dadrum, wie kann man da dann Betriebsmodelle, ähm, entwickeln, äh, für größere Einheiten, ähm, wie stellt man sich da auf mit Wartungsverträgen und sowas.‘

‘Somehow, I have the feeling we were ahead of the times.’
Interviewee_10, l.303: ‘Irgendwie waren wir damit unserer Zeit voraus habe ich das Gefühl.‘

‘[…] more demonstrators or pilot projects are needed, that one can see, what is actually realistically possible, what can be achieved with this system’
Interviewee_7, l.389ff.: ‘[…] muss es auch noch mehr Demonstratoren geben oder mehr Pilotvorhaben, dass man mal sieht, was ist eigentlich realistisch möglich, was kann man erreichen mit diesem System.‘

‘[…] it would be good, if this would spread a bit, yes, that it works’
Interviewee_4, l.398f.: ‘[…] das wäre gut, wenn sich das mal auch ein bisschen verbreitet, ja, dass das funktioniert.‘

‘[…] to be courageous, just try out new things’
Interviewee_5, l.338: ’[…] mutig sein, einfach mal neue Sachen ausprobieren.‘

Appendix C

Interview Guides

Interview Guide - Project Management:

1. Introduction:

- Introduce myself, tell what the goal of the interview is and how long it will approximately take
- Ask for permission for recording
- Ask if want to be anonymized
- Ask if want to see the transcript
- Explain that can take back answers and stop recording
- Ask exact position of person and task for the project

2. Questions (bullets are the actual questions, brackets and arrows just possible follow-up questions or supporting suggestions, depending on how the interview evolves)

- General questions and beginning of the project

- Why was this kind of project initiated?
  → What was a determining factor?
  → By whom? (usually more developer or city?)
  → How was the project initiated?

- Who was involved?
  →How?
  Can you consider that the project had several 'stages'? If yes, which kind? Was there a difference in involvement at different stages of the project?
- How and at what time of the planning process were technical experts involved?
  → By whom?
- Why was this particular place chosen?
  → Are there any special advantages?

- What made this project special for you?

- Evaluation of robustness/adaptability

- How is the project going now, after finishing the construction? (what problems appeared, did moving in go smoothly?)

- Is there flexibility in how to manage the site? (e.g. change in ownership, connecting new developments, adjusting technologies)

- Did it already have to prove itself in an extreme situation? (e.g. flood or dry times)

- Legal and financial issues

- How was the project financed and were there any difficulties in the financing? (for instance, due to ownership reasons)
  →what about subsidies?
  →if yes, how were these difficulties solved?

- Were there legal hindrances?
  → e.g. concerning planning permission, regulations for water supply

- What kind of permits were needed? And were there different then in the case of a 'regular' project?

- Residents/public: Involvement and impact

- What are legal differences for the residents? (e.g. responsibility for quality/safety)

- What are financial differences (have to pay more or less)?

- When you walk through the neighbourhood, would you notice any difference in terms of physical elements of the system? If yes, can you give examples?

- (How) was the public involved? (why)

- Was there any resistance concerning this project?

- Retrospective, main points, upscaling

- If you would do this project again, what would be three things that you would do differently?
- What would be the main things that you would definitely do in the same way?
  → What do you recommend to other, similar projects which are just getting started? And what to projects that have a water system already installed but want to change?

- What do you think was an important feature helping the progress of the project? (e.g. public support, an engaged individual, etc.)

- What do you think hindered or slowed the progress? (For instance, concerning technological problems)

- Do you see the possibility of a larger implementation (neighbourhood or city level) of this kind of projects? (Why?) (also concerning the replacement of existing infrastructure)

3. Final words

- Is there anything you would like to add that I did not think about?

- Ask for helpful documents about the project and other potential interview partner

- Ask if the interviewee would want to get a copy of the final thesis

- Thank you

Interview Guide – Municipality:

1. Introduction:

- Introduce myself, tell what the goal of the interview is and how long it will approximately take
- Ask for permission for recording
- Ask if want to be anonymized
- Ask if want to see the transcript
- Explain that can take back answers and stop recording
- Ask exact position of person and task for the project

2. Questions (bullets are the actual questions, brackets and arrows just possible follow-up questions or supporting suggestions, depending on how the interview evolves)

- General questions and beginning of the project

- Why was this kind of project initiated?
  → What was a determining factor?
  → By whom? (usually more developer or city?)
  → How was the project initiated?

- Who was involved?
  →How?
- Can you consider that the project had several 'stages'? If yes, which kind? Was there a difference in involvement at different stages of the project?
- How and at what time of the planning process were technical experts involved?
  → By whom?
- Why was this particular place chosen?
  → Are there any special advantages?

- What made this project special for you?
- What role did you have? Issuing permits? Is this different than in 'regular' projects?
- Do you encourage such projects in your strategic plans / policies? How? (if no – why not?)
- Do you have any subsidies or other forms of support or advising available for projects like this?
- Has the number of applications increased in the last year / after you introduced your support measures?
- Is there any pressure from the EU / national level for new ways of water management? Are there any stimuli from these levels?
- Do you see this project as experimentation or learning? (gibt es learning mechanism?)

- Evaluation of robustness/adaptability

  - How is the project going now, after finishing the construction? (what problems appeared, did moving in go smoothly?)

  - Is there flexibility in how to manage the site? (e.g. change in ownership, connecting new developments, adjusting technologies)

  - Did it already have to prove itself in an extreme situation? (e.g. flood or dry times)

- Legal and financial issues

  - How was the project financed and were there any difficulties in the financing? (for instance, due to ownership reasons)
    →what about subsidies?
    →if yes, how were these difficulties solved?

  - Were there legal hindrances?
    → e.g. concerning planning permission, regulations for water supply

- Residents/public: Involvement and impact

  - What are legal differences for the residents? (e.g. responsibility for quality/safety)

  - What are financial differences (have to pay more or less)?

  - When you walk through the neighbourhood, would you notice any difference in terms of physical elements of the system? If yes, can you give examples?

  - (How) was the public involved? (why)

  - Was there any resistance concerning this project?

- Retrospective, main points, upscaling

  - If you would do this project again, what would be three things that you would do differently?
  - What would be the main things that you would definitely do in the same way?
    → What do you recommend to other, similar projects which are just getting started? And what to projects that have a water system already installed but want to change?

  - What do you think was an important feature helping the progress of the project? (e.g. public support, an engaged individual, etc.)

  - What do you think hindered or slowed the progress? (For instance, concerning technological problems)

  - Do you see the possibility of a larger implementation (neighbourhood or city level) of this kind of projects? (Why?) (also concerning the replacement of existing infrastructure)

3. Final words

- Is there anything you would like to add that I did not think about?
- Ask for helpful documents about the project and other potential interview partner
- Ask if the interviewee would want to get a copy of the final thesis
- Thank you