Policy instrument mixes for operating modular systems within hybrid water infrastructures

Abstract

Water systems are experiencing dynamic societal demands and extreme environmental changes. The integration of modular water systems into existing centralized infrastructures could mitigate these challenges by enabling more resilient water management. However, the existence of technological alternatives has not changed the continuous reliance on centralized water infrastructure. Supportive policy instruments are key to foster the reliance on modular water systems. This article focuses on the role of substantive and procedural policy instruments for the successful operation of modular water systems within a hybrid water infrastructure. Based on Qualitative Comparative Analysis (QCA), we can confirm the claim in the literature that relying on regulatory instruments is relevant for operating decentralized technology. However, we also find combinations of policy instruments where regulatory instruments do not matter. Furthermore, we find that procedural instruments emphasizing stakeholder participation interplay with different substantive policy instruments to support the successful operation of modular systems.

Keywords: *water governance, modular water systems, hybrid water systems, policy instruments, QCA*

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Introduction

Centralized water infrastructures, including wastewater, water supply and (storm-) rainwater systems, are increasingly under pressure (Sedlak 2014; Domènech 2011). The expanding yet at the same time ageing structures and their usual top-down organization lack the flexibility to adapt to the 21st century's megatrends such as population growth coupled with continued urbanization and climate change-related extreme weather events (van de Meene et al. 2011; Larsen et al. 2016). The introduction of modular water systems, characterized by decentralization, mass production, increased scalability and automation, into centralized infrastructures creates hybrid systems with high systemic variation and long-term adaptive capacity that could enable potentially more resilient and resource efficient water management (Dunn et al. 2017; Eggimann et al. 2018; Larsen et al. 2013).[1] Moreover, the implementation of modular systems at the local scale could encourage more sustainable forms of environmental governance through local empowerment and shared responsibility (Biggs et al. 2009).

Nonetheless, the existence of modular technological alternatives has not changed the continuous reliance on completely centralized infrastructures (Eggimann et al. 2018; Kiparsky et al. 2013). A more widespread application of modular water systems seems to be a policy rather than a technological challenge (van de Meene et al. 2011; Eggimann et al. 2018; Yu et al. 2012). Policies can foster change, but there are different types of policy instruments with varying effects on desired outcomes (Capano and Lippi 2017). For instance, Partzsch (2009) identified economic instruments, such as subsidies or fees, as supportive for creating horizontal actor cooperation for operating decentralized systems. García Soler et al. (2018) confirm the importance of economic instruments in conjunction with regulatory and informational instruments. Additionally, Moglia et al. (2011) discuss procedural policy instruments, such as participation and responsibility, as important tools for creating enabling environments for decentralized water systems.

However, the relevant literature focuses exclusively on decentralized systems without considering their embedment in more complex hybrid systems. Furthermore, these studies do not focus on technical particularities of the issues that might require different instruments. Finally, from a theoretical perspective, these studies on decentralized systems largely neglect the interplay between different policy instruments, leaving the question *what configurations*

[1] Modular water systems are decentralized solutions that are distinguishable from other technologies by their specific features - most importantly modularity, meaning that the systems are treated as single modules, which are mass-producible and scalable. In the context of this paper, we use the terms "modular" and "decentralized" interchangeably, as the findings are applicable to decentralized solutions in general.

of policy instruments are supportive for successfully operating modular water systems within hybrid infrastructures ultimately unanswered.

Previous research has focused on single cases or countries (Biggs et al. 2009; Hamidov et al. 2015) or the impact of single policy instruments achieving a particular policy goal (Tapsuwan et al. 2014). By comparing seventeen cases – across a range of different governance situations – that already integrate decentralized systems into a centralized infrastructure, this study identifies commonalities in terms of policy instrument mixes across successfully operated modular water systems within hybrid infrastructures. The comparative analysis relies on fuzzy-set Qualitative Comparative Analysis (QCA). As we calibrate the policy instruments for the QCA analysis and investigate the role of procedural instruments in policy instruments mixes, we aim to contribute to Howlett and Capano's policy instrument research agenda, which identifies knowledge gaps, such as the calibration of substantive and procedural instruments and the role of procedural instruments in policy instruments mixes, requiring further investigation (Howlett and Capano, 2019).

This article proceeds with a theoretical discussion on substantive and procedural policy instruments that might matter for successfully operating modular water systems. After explaining our case study approach and describing our data sources, we present the results of the fuzzy-set QCA. We then discuss the configurations of conditions for the successful operation of modular systems, and conclude the analysis with a critical discussion.

Theoretical expectations about policy instruments

Policy instruments can support the introduction and diffusion of technologies. However, there is a lack of understanding about the relationship between the different types of instruments and the successful implementation and operation of technological alternatives (Mickwitz et al. 2008). Governments have most commonly relied on substantive policy instruments, which directly affect the delivery of goods and services, for reaching policy goals in the context of environmental governance, including the water sector (Pahl-Wostl 2015; Vedung 2010; Lascoumes and Le Gales 2007; Gunningham et al. 1998). Drawing on the policy instrument literature (Vedung 2010, Peters and Van Nispen 1998), three types of substantive instruments have been important for environmental governance: regulatory, economic and informational instruments. [2] Following Hood's (1986) taxonomy, these instruments draw on the

[2] Informational instruments are also considered as procedural rather than substantive instruments. However, depending on the type of informational instruments and the desired outcome, they can be either substantive or

governments' resources of authority (regulatory), treasure (economic) and nodality/ information (informational) for their effectiveness.

These substantive policy instruments are effective mostly in combination. For example, Gunningham et al. (1998) find that it is important to stimulate regulatory strategies, informational tools and subsidies simultaneously in the context of environmental policy. These can be mutually reinforcing, e.g., the use of informational tools can help inform policy addressees about regulatory and incentive instruments. Nonetheless, the extant literature notes the predominance of regulatory instruments in environmental governance with economic and informational tools serving a rather supporting role (Pierre and Peters 2000; Holley et al. 2012; Héritier and Lehmkuhl 2011). Given the current path dependency of policy instrument use, we expect *regulatory instruments need to be present in order to achieve the outcome*.

Substantive instruments alone might not be sufficient to alter the policy targets' behavior (Howlett 2000). Particularly given the characteristics of modular technology, various adaptations in the policy set-up are necessary to operate them as part of hybrid water infrastructures (Kiparsky et al. 2013; Yu et al. 2012). For instance, the small-scale and local nature of the modular systems encourages more collaboration and local self-organization, and therefore, it might require less top-down structures and a stronger involvement of a diverse range of public and private actors (Daniell et al. 2015). Procedural instruments can facilitate cooperation between societal actors and thereby complement substantive tools by increasing the overall flexibility of policy instrument mixes, tackling governance failures such as limited administrative capacity, information asymmetries or inefficiencies of public service delivery (Bouma et al. 2019; Howlett 2000, 2019). Procedural instruments fostering participation of stakeholders and users or responsibility for users can play a critical role in the reorganization of water services, relying on the governments' resource of organization (Howlett 2000, 2019; Schmidt 2013; Hood 1986). Participation democratizes processes by giving the actors a voice to influence policy, which can foster policy adoption (Beisheim and Dingwerth 2008; Considine and Lewis 2003). Bakker and Cook (2011) have found that the inclusion of users or local communities has fostered the implementation of policy goals in the context of Canadian water governance. Responsibility refers to actors being answerable or accountable for a certain task (Bovens 2007). Traditionally, governmental and producer or corporate responsibility have played a critical role in centralized water service provision – and the environmental policy sector as a whole (Lim and Schoenung 2010). For example, in waste

procedural instruments (Howlett 2019; Shroff et al. 2012). We further discuss the relation between informational instruments and procedural instruments in the discussion of results.

management, the extended producer responsibility (EPR) has been employed as an instrument to foster environmentally friendly products and to promote recycling, but this has not directly targeted the actual consumers (Lim and Schoenung 2010; Runkel 2003; Forslind 2005, Brouillat and Oltra 2012). Indeed, modular technology might require the allocation of responsibility to its users for its successful operation at the local scale (Daniell et al. 2015), due to the immediate impact of a households' behavior on the functioning of the system. This means that a policy holds users responsible for the operation and maintenance of a certain technology, leading to different configurations of shared responsibility between public and private actors. Although there is a consensus on the importance of policy instrument mixes for reaching policy goals (Lascoumes and Le Gales 2007; Gunningham et al. 1998), it is largely unknown how different policy instrument types such as substantive and procedural instruments interplay (Howlett 2000, 2019). Our second expectation is thus that *a combination of procedural policy instruments and substantive instruments leads to successful operation of hybrid systems.*

Figure 1 graphically summarizes our theoretical model. The model focuses on policy instrument mixes, but there are of course other factors influencing the successful operation of hybrid systems, such as e.g. actor constellations or institutional context, which we discuss in relation to our results. We assume the different policy instrument configurations to impact the operation of water systems, leading to a more or less successful provision of water services. Public services and in particular water services are expected to be delivered regularly at a certain quality and at an affordable cost (Finger and Finon 2011). Consequently, hybrid water systems can be considered as operating successfully if they provide the same or better quality of water services than infrastructures without modular elements.

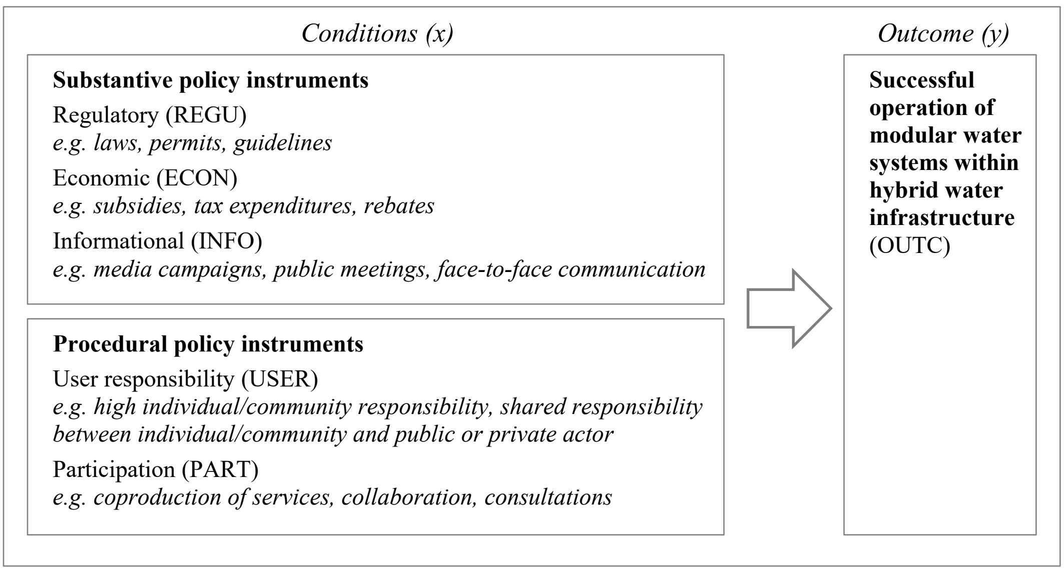

Figure 1: Own illustration of the interplay between conditions and outcome

Methods

Case selection

We take a medium-N comparative case study approach in order to identify important patterns between conditions (different types of policy instruments) and the outcome (successful operation of modular water systems) (Agranoff and Radin 1991; Yin 2014). Given the medium number of cases, we not only identify general patterns, but also focus on individual cases and take a diversity of case contexts into account.

We first conducted an extensive literature review (see Pakizer and Lieberherr, 2018) and eight expert interviews (see Appendix 8). Based on information from these sources, we purposefully selected cases based on the following criteria:

- Cases had to be hybrid systems (we excluded cases of complete decentralized water infrastructures, based on the assumption that there are different challenges for the implementation of modular systems in an environment where there is no established system).
- Cases had to represent different types of water systems including wastewater, water reuse and (storm-) rainwater (see Appendix 1). Although these water systems exhibit technical differences, which might necessitate specific regulations, all of them share the challenge of having to integrate decentralized into centralized systems.
- Cases could be countries as well as federal states/provinces, cities and municipalities, as we took the respective scope of the policies concerning modular systems into consideration.

This resulted in the selection of seventeen cases that have an established water infrastructure with new decentralized elements (see Appendix 1).

Qualitative Comparative Analysis

As we assume that different combinations of *regulatory instruments*, *economical instruments*, *informational instruments, user responsibility* and *participation* lead to the occurrence of the outcome, we apply Qualitative Comparative Analysis (QCA). QCA allows for "multiple conjunctural causation" to be observed. As compared to other methods such as regression approaches, QCA allows for the possibility that different combinations of conditions (solution paths) can lead to the same outcome, and that a given condition can have different effects on the outcome, depending on its combination with other conditions (Rihoux and Ragin 2009; Schneider and Wagemann 2012). These assumptions are not only appropriate for analyzing policy instrument mixes, but for many other social phenomena. For example, Hamidov et al. (2015) have used QCA to show how two configurations of three conditions (appropriate chairmanship skills, sustainable resource appropriation and effective participatory water governance) can lead to well-maintained irrigation canals in Uzbekistan.

Related to the focus on multiple configurational causation, QCA has a strong focus on cases and their specific contexts, and is thus appropriate for analyzing a small to medium number of cases, such as in this study (Rihoux and Ragin 2009; Schneider and Wagemann 2012). Conditions are represented as fuzzy-sets with theory-driven values that define degrees of set membership and non-membership. Fuzzy-set QCA can represent differing degrees to which a condition is present in a case with three qualitative anchors that determine complete presence (1), complete absence (0) and a crossover point (0.5) (Schneider and Wagemann 2012). QCA then analyses whether single conditions (x) or their configurations ($x_1 + x_2 + x_3 \ldots$) represent supersets (indicating potentially necessary conditions) or subsets (indicating potentially sufficient conditions) of the outcome (y) (Rihoux and Ragin 2009). Necessary conditions are conditions that need to be present in order for the outcome to occur, but the presence of a necessary condition does not automatically lead to the outcome. Sufficient (combinations of) conditions are conditions that always produce the outcome, but other conditions also produce the outcome. These conceptions of necessity and consistency are in line with QCA's focus on "multiple conjunctural causation" (see e.g. Rihoux and Ragin 2009).

Conditions, calibration rules and data analysis

We apply four value-fuzzy sets: The boundary of the sets is between the anchor points 0 and 1 with two additional thresholds, 0.33 and 0.67, making 0.5 a crossover point without empirical value. We include the thresholds of 0.33 and 0.67 in order to be able to express qualitative differences (Rihoux and Ragin 2009). The calibration procedure and rules for assessing the fuzzy-set membership values for each case on each of the five conditions appear in Appendix 2.

The data were generated from documents identified through a literature review. We analyzed 2-3 documents per case, consisting mostly of secondary literature (peer-reviewed articles, project reports and official presentations) as well as government, NGO and professional association reports (see list of documents per case in Appendix 1). A potential downside of relying on documents as a main data source is that in cases with a lack of documents, there is a lack of information for assessing membership scores. However, documents were available for all our cases, and in case there was uncertainty on the appropriate membership scores given missing information in the documents, we conducted informal interviews with experts on some of the cases (see Appendix 8). The analysis was performed with the *QCA* (Duşa

2019) and *SetMethods* (Oana et al. 2018) packages in R.

Results

Necessity and sufficiency of conditions

We first assess the potential necessity of the five conditions for the outcome (successful operation of modular water systems within hybrid water infrastructure) by considering the consistency (inclN)[3] and the two coverage (RoN, convN) scores[4]. The conditions' consistency and coverage scores reveal that none of the policy instruments can be considered a necessary condition for the presence or the absence of the outcome (see Appendix 3).[5]

The sufficiency analysis is based on the creation of a truth table[6] that lists all possible combinations of conditions and assesses the sufficiency of these combinations of conditions for the outcome (based on the consistency of the subset relation between the combination of conditions and the outcome). There are 32 logically possible combinations of the five conditions (presence or absence of three substantive policy instruments and two procedural policy instruments). Eight of them are empirically observed and listed in the truth table, leaving us with 24 logical remainders (see Appendix 4).[7] From the eight configurations in the truth table, five configurations can be regarded as sufficient for the outcome, whereas three configurations are not consistently leading to the outcome.[8] The set of configurations in the truth table is then minimized by eliminating non-relevant conditions, which results in the identification of an intermediate solution consisting of three paths as sufficient for the outcome.[9]

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[3] The consistency score denotes to which degree a condition is consistent with the statement of necessity, meaning the degree to which each cases' membership in a condition (X) is equal or greater than their membership in the outcome (Y) (Schneider and Wagemann 2012).

[4] Schneider and Wagemann (2012) proposed the RoN score as a modified version of the coverage score convN, which is used for examining the relevance of a necessary condition by assessing how much smaller the outcome set is in relation to a condition set. High values indicate relevance, while low values suggest trivialness of the necessary condition (an example of a trivial necessary condition would be: oxygen is necessary for life).

[5] We refrain from interpreting conjoint necessary conditions ("X *or* Y is necessary"), given that many different combinations of conditions fulfill the respective criteria, and interpretation is not straightforward, as with conjoint necessary conditions, no component of the conjunction is individually necessary.

[6] Truth tables are data matrices that consist of columns, which denote the sets, and rows, which represent the different combinations of conditions. The number of rows is calculated by the previously discussed paths 2^k (Schneider and Wagemann 2012).

[7] Logical remainders are configurations that have not been observed in the data, although hypothetically they could exist.

[8] We applied an inclusion / consistency threshold of 0.8, which corresponds to usual thresholds used for QCA analyses, as well as to a large gap in inclusion / consistency scores.

[9] The intermediate solution minimizes the solution by taking into account logical remainders in line with theoretical expectations (for all five conditions: presence of instrument fosters outcome). By contrast, the parsimonious and complex solutions make strong assumptions, as they either assume that any logical remainder

Path	*Solution*	*Cases*	*Consistency*	*PRI*	*Raw coverage*	*Unique coverage*
1	**REGU*INFO*PART**	France, Hamburg; Barcelona Metro, Berlin, Sweden; Ireland, Victoria, New South Wales, Ontario, San Francisco, Austria	0.88	0.84	0.67	0.21
	+					
2	**REGU*ECON*INFO*USER**	Japan; Ireland, Victoria, New South Wales, Ontario, San Francisco, Austria	0.84	0.79	0.49	0.03
	+					
3	**ECON*INFO*USER*PART**	Onondaga; Ireland, Victoria, New South Wales, Ontario, San Francisco, Austria	0.84	0.79	0.49	0.03
	=> OUTC					
				Solution consistency		0.89
				Solution PRI		0.86
				Solution coverage		0.73

Table 1: Solution formula after the minimization

Results appear in Table 1. There are three solution paths leading to an outcome of successful operation of modular water systems within hybrid water infrastructure, and overall, we see very good consistency and coverage measures. A consistency score of 0.89 means that the solutions are to 89% consistent with empirical evidence. A coverage score of 0.73 means that the solution covers 73% of the empirically observed variation. First, a combination of regulatory instruments, informational instruments, and participatory instruments leads to the outcome. This solution applies to 12 cases. Second, we observe a combination of regulatory instruments, economic instruments, informational instruments and user responsibility to be sufficient for an outcome of successful hybrid water governance. Third, the combination of

leads to the outcome (parsimonious solution), or that no logical remainder leads to the outcome (complex solution). Still, we present the parsimonious and complex solutions in the Appendix (see Appendix 5).

economic instruments, informational instruments, user responsibility and stakeholder participation leads to the outcome. The cases of Ireland, Victoria, New South Wales, Ontario and San Francisco are covered by all three solution paths. This also means that these cases include all five instruments, and are thus not particularly interesting to interpret. What is more important is that the cases of Onondaga (third solution path), Japan (second solution path), and France, Hamburg, Barcelona, Berlin and Sweden (first solution path) suggest that specific combinations of instruments are sufficient for producing the outcome.

As robustness tests, we clustered the cases around their implementation level (national, regional or local) and the type of water system (wastewater, water reuse or rainwater), followed by a QCA analysis within each cluster. The resulting solution formulas do not deviate significantly from the original solution, but correspond closely to at least one of the three paths of the original solution (see Appendix 6).

Illustration of solution paths

The first path consists of the conditions *regulatory instruments*, *informational instruments* and *participation*, which represents a mix between two substantive policy instruments and a procedural one. Interestingly, the conditions *informational instruments* and *participation* both have underlying mechanisms used for fostering citizen involvement (Head 2007). The simultaneous occurrence of both conditions could highlight the need to more strongly involve users and owners into the management of modular water systems. One instance of this path is the case of Sweden. Swedish households with decentralized wastewater systems are required to obtain a permit for the discharge of wastewater from the municipalities' environmental authority. Although this regulatory instrument requires the municipality to inspect and regulate wastewater systems outside the urban wastewater jurisdiction, it also necessitates cooperation with individual households in order to ensure that their wastewater systems meet the water quality standards (McConville et al. 2017). For this purpose, the households take over certain tasks, such as the bi-weekly emptying of the systems' dry feces fraction (Vinnerås and Jönsson 2013). In the particular case of Swedish on-site urine diversion systems, some municipalities even mandate the installation of such systems for all new residential developments (Fam and Mitchell 2013), a strong regulatory instrument that has implications for the management of the nutrient recovery systems, which is organized in a collaborative manner, as residents are actively involved in meetings and discussions about the development of the systems. Fam and Mitchell (2013) coined this type of approach as "social organization".

Another example for the interplay between *regulatory instruments*, *informational instruments* and *participation* is the case of the Barcelona Metropolitan Area. As already mentioned, the local municipalities used a building code to mandate the installation of decentralized rainwater harvesting systems in particular buildings. The homeowners and users are responsible for the operation and the maintenance of their rainwater and greywater reuse systems [10], thereby transforming from consumers to co-producers of water services. Consequently, the municipal authorities used different communication channels to inform them about the new regulation and the specificities of managing decentralized water systems. Such channels include websites, local bulletins, local media, organization of informational sessions, publication of handbooks or even the setup of information booths (Domènech and Vallès 2014). However, a survey revealed that the users had alarming knowledge gaps, especially concerning grey water systems, despite their expected participation in the systems' management (ibid.).

Regulatory and *informational instruments* are also present in the second path. A significant difference, however, is the presence of the conditions *economic instruments* and *user responsibility*, while the condition *participation* is absent, suggesting that economic incentives and the sharing of responsibilities with system owners and users could potentially balance a lack of participative measures. An example for such a configuration is the case of Japan. In addition to the extensive regulatory framework, the Japanese government set up an economic incentive portfolio to encourage homeowners as well as municipalities to install *Johkasous* (Gaulke 2006). The responsibility for the *Johkasous* is shared between prefectures, municipalities, private companies and users (Asian Development Bank 2016). Specifically for the users, this means that they are responsible for ensuring that the maintenance and desludging of their systems is taken care of, for keeping a documentation hereof and for paying the associated charges (Hirose 2018; Asian Development Bank 2016; Gaulke 2006). The Japanese society's long experience with decentralized wastewater systems could explain their unproblematic implementation (Gaulke 2006). Consequently, the government might not need to campaign for public acceptance or actively engage users through participatory mechanisms. However, the lack of participation might also lead to a lack of cooperation. For instance, although the Japanese Ministry of Health has set up a subsidy program to encourage the replacement of outdated *Johkasou* generations, which have even been forbidden since

[10] A professional company has to be hired for the new systems' maintenance during the first two years, however after that period, this responsibility falls on the users who should continue hiring someone to undertake these tasks. Although the city council supervises and authorizes the systems' setup, there are no capacities for controlling their operation regularly (Domènech and Vallès 2014).

2001, their replacement has only progressed slowly (Glauke 2006). The limited effect of subsidies here might illustrate the importance of combining economic instruments with engaging measures.

In the case of New South Wales, despite the application of multiple regulatory instruments in order to encourage the use of recycled water in residential schemes, *economic instruments* are used as well, for instance the price for recycled water is subsidized and thereby generally lower, being charged at about 80% of the fresh drinking water price (Anderson 2013). New South Wales also provided one-off grants to promote recycling and private investments (for example through the *NSW Governments Water and Energy Savings Fund*). However, this was only a temporary measure motivated by a severe drought period lasting from the year 2001 to 2009. Nowadays, funding for decentralized systems is calculated based how much they lead to avoided costs for the centralized infrastructure (Watson et al. 2017). The local authority's efforts to regulate and encourage decentralized water recycling systems are additionally supported by *informational instruments* such as public education programs. For instance, community meetings are organized and educational information is shared with households.

The water utility *Sydney Water* also established a water recycling education center at one of its water recycling plants with the purpose to educate students on water recycling technology (Anderson 2013). Moreover, specific education programs were created for local plumbers and contractors that work with recycled water systems, as they share responsibility with the users for the adequate functioning of systems. The users are responsible in particular for ensuring the proper installation of connecting parts, checking connections and meters and guaranteeing the compliance with plumbing, roofing and guttering standards. The case of New South Wales, but also the case of Victoria and San Francisco, represent water stressed areas (the description of the San Francisco case is included in Appendix 2), which have experienced episodes of droughts and water shortage in the past but also in the most recent years (Watson et al. 2017; Mukheibir and Currie 2016; Hughes 2012). The severeness of the cases' situation might explain the strong reliance and presence of all three substantive policy instruments.

The third solution path consists of all conditions except for *regulatory instruments*. This could be an indication that the absence of strong regulatory measures necessitates the application of all the other policy instruments in order to operate modular water technologies. One example for such a configuration is the case of Onondaga County in the U.S. state of New York. Although the county has no local regulations in place to require decentralized green infrastructure on the ground, it adopted a stormwater management plan *Save the Rain*, which supports the implementation of such technologies (Flynn et al. 2014). The program provides free rain barrels and residential trees for enhanced stormwater evapotranspiration in the portions of the county that have the highest priority for stormwater mitigation (Lieberherr and Green, 2018). The public was informed about the program through public outreach and education initiatives, including a social media campaign and the organization of live events, such as a festival or tree-planting events (Lieberherr and Green 2018). This approach illustrates in particular the interplay between informative with participatory measures, simultaneously informing and engaging the public. Additionally, as a consequence of previous public protests against the county's centralized wastewater infrastructure plans, locals are being involved at the planning stage of new projects, effectively creating structures for co-management (Flynn et al. 2014). Establishing an adaptive governance arrangement, the responsibility is shared between County and City governments, private businesses, NGOs and the residents of Onondaga County.

Although regulatory instruments are present in the Irish case, they have led to operationally deficient on-site wastewater treatment systems, which is in particular worrisome as they are often situated near private wells and group water schemes (Hynds et al. 2018). Consequently, the European Court of Justice ruled against Ireland in 2009 for failing to fulfill the requirements of Art. 4 and 8 of the European Directive 75/442/EEC. Ireland was found guilty for not adopting the necessary legislation to the adequate treatment of waste, which following the court's ruling also includes wastewater. Over the next years, Ireland was repeatedly fined for not complying with its responsibilities (e.g. case C-374/11). This legal step can be interpreted as the European Commission forcing the Irish government to be more involved in the implementation and operation of domestic wastewater treatment systems, which culminated in the adoption of the Water Services (Amendment) Act (WSA) in 2012. Although the WSA has been repeatedly amended over the years, it still lacks the necessary assertiveness, as it contains cautious and often vaguely formulated institutional statements with only little deterring effect. Moreover, the WSA provides no strategies that instruct the users in the maintenance of their systems, which is in particular problematic as the users are mainly responsible for their systems' adequate functioning. A third of these systems failed inspections during 2013-2018 and the government has tried to address this deficit with a grants scheme, which is supposed to encourage the users to upgrade their malfunctioning systems. However, the scheme has been rarely seized, facing a low uptake of 5 %, as it can only be claimed after being officially inspected and having failed. As a consequence, there are no incentives to upgrade malfunctioning systems without having previously failed an inspection (Engineers Ireland 2018; Mooney 2015). Another measure by the government was the implementation of a vast communication campaign, consisting of informative leaflets to be distributed across the country by to local authorities and other relevant bodies (e.g., group water schemes) and a segment dedicated to wastewater treatment was included in the national television program Ecoeye. Additionally, at the local level, emails and letters were sent to registered owners as well as info packs and leaflets. The local authority also used website and social media notices, newspaper ads and articles, radio interviews and ads, school visits, pre-inspection visits and stakeholder meetings. Nonetheless, this comprehensive strategy failed to substantially change the users' behavior and consequently, a significant percentage of the decentralized wastewater treatment systems continue to be operationally deficient (Hynds et al., 2017; Mooney, 2015). The case of Ireland but also the case of Barcelona metropolitan area both highlight the importance of applying adequate and tailored informational instruments for informing and educating target groups.

Discussion

Given the fact that two out of three paths include regulatory instruments with a strong reliance on laws, permits and ordinances for the successful operation of decentralized technology, the results largely support our first expectation, which is also in line with studies on policy reforms that have shown the key role of regulatory instruments as central in the water sector (Lieberherr and Fuenfschilling 2016). Two possible explanations seem relevant in this context. First, although there are many different values assigned to water and water services, there is a strong link to the "public good" norm that delineates water as a human right - a notion that was even codified in a United Nations resolution - and public resource that should be provided and protected by any government (Noga and Wolbring 2013). Political actors might fall back on regulatory policy instruments to ensure this responsibility is met. Consequently, regulatory instruments might represent a recurrent path element that is rooted in governments' traditional reliance on laws and ordinances, which have proven to be effective in the past and have therefore become routinized, corresponding to the logic of consequence in instrument choice theory (Capano and Lippi 2017). Second, scholars argue that strong regulatory instruments are necessary for sustainability and technological innovations (and modular water systems can be considered as such), as they are able to overcome lock-in tendencies and to open up the participatory and political space for envisioning and implementing new water technologies (Ashford and Hall 2011). For instance, the Japanese central government specifically formulated a regulatory framework (*Johkasou law*), which mandates the usage of the domestic wastewater treatment system *Johkasou* for new constructions in areas without sewers or with a large building footprint (Gaulke 2006). Similarly, the local municipalities in the Barcelona metropolitan area used a building code that mandates the installation of decentralized rainwater harvesting systems in buildings with more than 300m2 gardens and new constructed buildings (Domènech and Saurì 2010; Domènech and Vallès 2014). In San Francisco, the city designated recycled water use areas that are required to install onsite water systems, which was later even expanded to the entire city (SF Water 2015; Kehow 2016).

With regard to our second expectation, the presence of procedural instruments in all the identified paths provides empirical support for the important role of procedural instruments for the successful operation of hybrid systems. Our results indicate that the input side of legitimacy, which is linked to the quality of a process in terms of participation and access to decision-making, is important for the successful operation of modular water systems. Consequently, the inclusion of such an instrument could be explained by the logic of appropriateness, following the principle of legitimacy (Capano and Lippi 2017).

The results confirm the importance of policy instrument mixes for steering and operating complex settings and multi-faceted challenges (Wilts and O'Brien 2019; del Rio and Howlett 2013; Doremus 2003) that is modular infrastructure in hybrid water systems. Our identified mixes seem to be also in line with the "smart regulation" concept that advocates for mixes making use of the wide range of policy instruments, including procedural instruments responsive to the context-specific characteristics of the policy sector and empowering third party participation (Gunningham et al. 1998; Howlett and Rayner 2007).

We observe that several policy instruments of the same type are applied, especially in regard to regulatory instruments. Multiple instruments of the same type might be used to address different aims, ranging from abstract overarching goals (e.g. in form of laws) to more specific implementation preferences (e.g. permits, technical standards) (Howlett 2009). For instance, in the case of France, laws, technical standards and system certification procedures are used to regulate on-site wastewater systems. Another possible explanation for the usage of multiple policy instruments of the same type could be the presence of multi-level governance arrangements, necessitating instrument configurations that address different levels in order to integrate horizontal and vertical dimensions of policy-making (Howlett et al. 2017).[11] For instance, although the French central government used to hold the main responsibility for

[11] The presence of multiple instruments might also be an indicator for policy instrument layering, adding instruments on top of another, which are not necessarily complementary (Howlett et al. 2017). However, we do not find any particular evidence for that in our cases.

these decentralized systems, a reform in 2006 transferred these competencies to the municipalities and in particular to the local public service solely dedicated to these systems called *Service Public de l'Assainissement Non Collectif* (SPANC) (Fouché et al. 2017).

Conclusions

In the context of increasing societal demands and extreme environmental changes challenging centralized water infrastructures, modular water systems have the potential to enable more resilient and resource efficient water management (Eggimann et al. 2018; Larsen et al. 2013). We have thus addressed the question of *what configurations of policy instruments are supportive for successfully operating modular water systems within hybrid infrastructures.*

Our analysis of 17 cases across a range of governance situations (governance levels from local to national and substantive issue areas such as wastewater, water reuse, rainwater) has shown that policy mixes of both substantive and procedural instruments are key for the successful operation of modular water systems within hybrid water infrastructure. Interestingly, we do not find regulatory instruments in all paths, as we would have expected; although their presence in two out of three paths shows their importance. Instead, we find informational instruments in all three paths, which might indicate the importance of information dissemination in the context of new technologies. Moreover, informational instruments might be key to link substantive and procedural instruments. Concerning procedural instruments, we find that participation and user responsibility interplay with different substantive policy instruments to support the successful operation of hybrid systems by engaging locals.

Results from this study only provide a "snapshot" of the current usage of policy instruments mixes for modular systems. Future research should consider the temporal dimension, investigating the sequencing of instruments. Researchers might also consider examining the effectiveness of mixes, identifying potential trade-offs between the instruments and their goals. Moreover, we attempted to provide some explanation for the choice or reliance on a particular policy instruments, but a deeper analysis of the underlying logics would be still desirable, investigating whether the choice of policy instruments could ultimately depend on the availability of the government's resources (Howlett 2019).

Notwithstanding these limitations, this article makes several contributions to the literature. First, we contribute evidence about the important role of input-oriented legitimacy for arriving at a certain outcome, given the important role of procedural instruments for the successful operation of water infrastructure systems. Second, we show that a diversity of policy instrument configurations matters in this sector, in line with Ostrom (2005) showing that there is no silver bullet to policy instruments and policy design. By considering a range of policy instruments – both substantive and procedural – we provide insights on different mechanisms influencing the operation of hybrid water systems.

Third, given the diversity of governance situations represented in our cases and our respective robustness tests, we believe that our findings are not unique to specific situations, but are valid across a range of governance levels and apply to substantive problems related to wastewater, water reuse, and rainwater, and probably to other issues related to the hybridization of infrastructures. This study contributes to this literature by analyzing a diversity of cases as well as mixes of policy instruments.

Finally, we contribute to the research agenda on policy instrument analysis set out by Howlett and Capano (2019) by providing insights on the calibration of substantial and procedural instruments, on the one hand, and the role of procedural instruments in policy instruments mixes, on the other (Howlett and Capano 2019). Specifically, the following findings on combinations of instruments stand out: all three identified solution paths consist of a combination of both substantive and procedural instruments. Our results further suggest that one single substantive instrument is never enough, but at least two are needed. Moreover, informational instruments are always part of the combination of instruments, whereas only one procedural instrument is needed if the substantive instrument is a regulatory one. If there is no regulatory instrument, this can be compensated by a strong procedural part, consisting of both user responsibility and stakeholder participation. We thus highlight the value of not only instrument mixes but also the specific interplay between procedural and substantive policy instruments to address complex environmental governance issues, such as water systems.

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Appendix

1. Cases: Technology and reviewed documents

Case	Technology	Documents
Japan	On-site wastewater treatment system (Johkasou)	• Gaulke, L. S. (2006) "On-site wastewater treatment and reuses in Japan", *Water Management* 159(2), 103-109. • Hirose, Y. (2018) *Decentralized wastewater treatment system and its legal framework in Japan*, Presentation at United Nations Centre for Regional Development, April 2018. • Asian Development Bank (2016) *Sanitation and Sustainable Development in Japan*, Report.
Ireland	On-site wastewater treatment system (mostly septic tanks)	• Hynds, P., Naughton, O., O'Neill, E. and Mooney, S. (2017) "Efficacy of a National Hydrological Risk Communication Strategy; Domestic Wastewater Treatment Systems in the Republic of Ireland", *Journal of Hydrology* 588, 205-213. • Mooney, S. (2015) *Domestic Wastewater Treatment in Ireland: Septic Tanks. A Report on the Progress of the National Inspection Plan (2013-2015)*, Report for An Taisce. • Engineers Ireland (2018) *The State of Ireland 2018. A Review of Infrastructure in Ireland*, Report.
Melbourne	Household rainwater tanks and water recycling schemes	• Ferguson, B.C., Brown, R.R., Frantzeskaki, N., de Haan, F.J. and Deletic, A. (2013) "The enabling institutional context for integrated water management: Lessons from Melbourne", *Water Research* 47(20), 7300-7314. • South East Water (2019) *Aquarevo: A New Way of Living*, Website • Fam, D., Mitchell, C. and Abeysuriya, K. (2014) "Emergence of decentralized water and sanitation systems in Melbourne", *International Journal for Water* 8(2), 149-165.
British Columbia	On-site wastewater treatment system (mostly septic tanks)	• Sewerage System Regulation Improvement Coalition (SSRIC) (2009) *Reforming the Regulation of BC's Sewerage Systems: An Urgent Need to Protect Public Health*, Report. • Government of British Columbia (2018) *Sewerage System Regulation Amendments*, Amendment text.
Ontario	On-site wastewater treatment system (mostly septic tanks)	• Dumencu, G. C., Wang, Y. and Stefan, W.G. (2016) *Two Case Studies: Delivery of Decentralized Wastewater Solutions in Ontario and India*, Conference paper, CSCE Annual Conference (London, 1-4 June 2016) • Ontario Ministry of Agriculture, Food and Rural Affairs (2010) *Septic Smart! Understanding your Home's Septic System*, Booklet 1 • Ontario Ministry of Agriculture, Food and Rural Affairs (2010) *Advanced Treatment Systems – Alternatives to Conventional Septic Systems*, Booklet 2 • Federation of Ontario Cottagers' Association (2019) Septic Re-inspection Programs in Ontario, Report
Sydney	Water recycling systems	• Watson, R., Mukheibir, P. and Mitchell, C. (2017) "Local recycled water in Sydney: A policy and regulatory tug-of-war", *Journal of Cleaner Production* 148, 583-594. • Anderson, J. (2013) "Australia's urban and residential water reuse schemes", in: Lazarova, V., Asano, T., Bahri, A. and Anderson, J. (Eds.) *Water Reuse. The Best Success Stories*, London: IWA Publishing, Chpt. 11. • Mukheibir, P. and Currie, L. (2016) "A whole of water approach for the city of Sydney", *Water Utility Journal,* 12, 27-38.
San Francisco	Water recycling systems	• SF Water (2015) *San Francisco's Non-potable Water Program. A Guidebook for Implementing Onsite Water Systems in the City and*

		County of San Francisco, Guidebook. • Kehow, P. (2016) *San Francisco's Non-Potable Water Program*, Presentation.
New York Onondaga	Rainwater harvesting systems	• Flynn, C., Davidson, C. and Mahoney, J. (2014) *Transformational Changes Associated with Sustainable Stormwater Management Practices in Onondaga County*, Conference Paper, ICSI 2014: Creating Infrastructure for a Sustainable World (Long Beach, 6-8 November 2014). • Lieberherr, E. and Odom Green, O. (2018) "Green Infrastructure through Citizen Stormwater Management: Policy Instruments, Participation and Engagement", *Sustainability* 10(6), 1-13.
Barcelona	Rainwater harvesting tanks	• Domènech, L. and Vallès, M. (2014) "Local regulations on alternative water sources: greywater and rainwater use in the metropolitan region of Barcelona", *Investigaciones Geográficas* 61, 87-96. • Domènech, L. and Saurì, D. (2010) "A comparative appraisal of the use of rainwater harvesting in single and multifamily buildings of the Metropolitan Area of Barcelona (Spain): social experience, drinking water savings and economic costs", *Journal of Cleaner Production* 19, 598-608. • Vallès-Casa, M., March, H. and Saurì, D. (2016) "Decentralized and User-Led Approaches to Rainwater Harvesting and Greywater Recycling: The Case of Sant Cugat del Vallès, Barcelona, Spain", *Built Environment* 42(2), 243-257.
UK	Rainwater harvesting systems	• Ward, S., Barr, S., Memon, F. and Butler, D. (2012) "Rainwater harvesting in the UK: exploring water-user perceptions", *Urban Water Journal* 10(2), 112-126. • Parsons, D., Goodhew, S., Fewkes, A. and De Wilde, P. (2010) "The perceived barriers to the inclusion of rainwater harvesting systems by UK house building companies", *Urban Water Journal*, 7(4), 257-265. • Environmental Agency (2010) *Harvesting rainwater for domestic uses: an information guide*, Bristol: Environmental Agency.
Berlin	Rainwater harvesting systems	• García Soler, N., Moss, T. and Papasozomenou, O. (2018) "Rain and the city: Pathways to mainstreaming rainwater harvesting", *Geoforum* 89, 96-106. • Million, A., Bürgow, G. and Steglich, A. (2018) *Roof Water-Farm. Urbanes Wasser für urbane Landwirtschaft*, Report, TU Berlin.
Sweden	On-site wastewater treatment systems and urine diversion	• McConville, J.R., Kvamström, E., Jönsson, H., Kärrman, E. and Johansson, M. (2017) "Source separation: Challenges & opportunities for transition in the Swedish wastewater sector", *Resources, Conservation and Recycling* 120, 144-156. • Fam, D. and Mitchell, C. (2013) "Sustainable innovation in wastewater management: lessons for nutrient recovery and reuse", *Local Environment* 12(1),769-780. • Vinnerås, B. and Jönsson, H. (2013) "The Swedish Experience with Source Separation", in: Larsen, T.A., Udert, K.M. and Lienert, J. (Eds.) *Source Separation and Decentralization for Wastewater Management*, London: IWA Publishing, 415-422.
Poland	On-site wastewater treatment systems	• Optitreat (2017) Maintenance regulation of small wastewater treatment facilities. Case studies in Germany, Poland and Sweden, Report, BONUS • Boguniewicz-Zabłocka , J.and Capodaglio, A.G. (2017) "Sustainable Wastewater Treatment Solutions for Rural Communities: Public (Centralized) or Individual (On-Site) – Case Study", *Economic and Environmental Studies*, 17:4, 1103-1119. • Mikosz, J. (2013) "Wastewater management in small communities in Poland", *Desalination and Water Treatment* 51(10-12), 2461-2466.
New Zealand	Rainwater harvesting tanks	• Bint, L., Garnett, A., Siggins, A. and Jaques, R. (2019) "Alternative Water Sources in New Zealand's commercial buildings", *Water Supply* 19(2), 372-381. • Gabe, J., Trowsdale, S. and Mistry, D. (2012) "Mandatory urabn rainwater harvesting: learning from experience", *Water Science & Technology*, 65:7, 1200-1207.
Austria	On-site wastewater treatment	• Langergraber, G., Pressl, A., Kretschmer, F. and Weissenbacher,

	systems	N. (2018) “Small wastewater treatment plants in Austria - Technologies, management and training of operators” • Land Oberösterreich (2006) *Ratgeber Abwasserentsorgung in Streulage*, Booklet
France	On-site wastewater treatment systems (mostly septic tanks)	• Da Costa, V., Jobard, E., Marquay, J., Ollagnon, M., Plat, B. and Radureau, S. (2015) *Public Water and Wastewater Services in France. Economic, Social and Environmental Data*, Report, BIPE. • Fouché, O., Deroubaix, J.-F and Nasri, B. (2017) “Origin and implementation of a new public policy for on-site sanitation in France: towards a global value chain of wastewater more responsible?”, *International Journal of Sustainable Development* 20(3-4), 1-22.
Hamburg	Water recycling schemes and rainwater harvesting	• Kreis (2012) *Kopplung von regenerativer Energiegewinnung mit innovativer Stadtentwässerung*, Brochure, FONA. • Schramm, E., Giese, T., Kuck, W. and Völker, C. (2016) “*Neuartige Sanitärsysteme in Umsetzung und Betrieb: Hinweise zum Kooperationsmanagement am Beispiel der Jenfelder Au in Hamburg*”, *gwf-Wasser/Abwasser* 157(2), 148-155. • Skambraks, A.-K., Kjerstadius, H., Meier, M., Davidsson, Å., Wuttke, M. and Giese, T. (2017) “Source separation sewage systems as a trend in urban wastewater management: Drivers for the implementation of pilot areas in Nothern Europe”, Sustainable Cities and Society, 28, 287-296.

2. Calibration rules

In order to clarify our calibration rules, we discuss the case of San Francisco as an illustrative example. Concerning the first condition, *regulatory instruments*, San Francisco was assigned the membership value of 1 due to the presence of strong regulatory instruments in form of ordinances (e.g. *Recycled Water Ordinance* or the *Onsite Water Reuse for Commercial, Multi-family, and Mixed Use Development Ordinance*, allowing the collection, treatment, and use of alternate water sources for non-potable applications), mandatory installations in designated areas (e.g. beginning November 1, 2015, all new development projects of 250,000 square feet or more of gross floor area located within the boundaries of San Francisco’s designated recycled water use areas must install onsite water systems, which was expanded to the entire city the following year) and mandatory water budget applications (e.g. developments between 40,000 and 250,000 square feet of gross floor area must submit a water budget application) (SF Water 2015; Kehow 2016). The condition *economic instruments* was also valued with the set-membership score of 1 due to the existence of grant assistance and subsidy programs e.g. for cisterns and rain barrels Laundry-to-Landscape (L2L) kits (Kehow 2016). As the used *informational instruments* in the San Francisco case focus on persuading about facts and options via local public outreach in form of dedicated web pages, technical workshops and fact sheets, we assigned this set the membership value of 0.67 (ibid.). As for the condition *user responsibility*, we ascribed the case the value of 0.67 based on the fact that onsite water systems in San Francisco are required to obtain an engineering/plumbing plan approval as well as plumbing, site, and building permits from the Department of Building Inspection (DBI) and the San Francisco Department of Public Health (SFDPH), which shows that responsibilities have not been completely transferred to individuals or communities. Moreover, district-scale systems must execute an enforceable legal agreement defining the roles and responsibilities of each property owner or entity, which further indicates that this a case of shared responsibility (SF Water 2015). The condition *participation* was assigned the set-membership value of 1, as there are many initiatives aiming at fostering collaboration. For instance, the *Watershed Stewardship Grant Program* funds sidewalk landscaping, rainwater harvesting and green infrastructure projects in the public realm with the goal to engage communities and provide opportunities for education and outreach (Kehow 2016). For the same purpose, free trainings, tech support and free tool lending are provided in order to stronger involve San Franciscan citizens (ibid.). Moreover, onsite system-owners are expected to provide access to their property for inspections and to participate in surveys, which necessitates their collaboration. In sum, the San Francisco case can be considered a very successful case, corresponding to the set-membership value of 1 for the outcome, as there are no mentions of any service provision constraints in the analyzed literature (Kehow 2016, SF 2015).

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Conditions	Set membership				Conceptualization based on:
	0	0.33	0.67	1	
Regulatory instruments	*No regulatory instruments* (E.g. voluntary schemes, codes of conduct)	*Less regulatory instruments* (E.g. guidelines, recommendations)	*Some regulatory instruments* (E.g. technical standards)	*Regulatory instruments* (E.g. laws, ordinances and licenses)	Vedung 2010; Pierre and Peters 2000; Hysing 2009; Lundqvist 2001; Sørensen 2006; Holley et al. 2012; Héritier and Lehmkuhl 2011; Jordan et al. 2005
Economic instruments	*No economic instruments* (E.g. no subsidies)	*Less economic instruments* (E.g. waiver of fees; rebates; less than 50% subsidized)	*Some economic instruments* (E.g. reduced-interest loans; loan guarantees; more than 50% subsidized)	*Economic instruments* (E.g. cash grants; tax expenditures; more than 75% subsidized)	Vedung 2010; Harrington and Morgenstern 2004; Partzsch 2009; Henstra 2015; Stanton 2002; Howard 2002
Information instruments	*No information instruments* (E.g. no communication channel or strategy)	*Less information instruments* (E.g. contact via mass media; presenting facts, options)	*More information instruments* (E.g. contact via local/regional outreach; persuading about facts, options)	*Information instruments* (E.g. direct personal contact; contact via face-to-face; direct appeals, stimulating self-commitment	Vedung 2010; Ostrom 2005 ; Poteete et al. 2010; Kemp et al. 1994
User responsibility	*No user responsibility* (E.g. political-administrative responsibility)	*Less user responsibility* (E.g. customer, shareholder/corporate oriented responsibility)	*More user responsibility* (E.g. shared responsibility between individual/community and public/privateactors)	*User responsibility* (E.g. high individual or community responsibility)	Bovens 2007; Lim and Schoenung 2010; Runkel 2003; Forslind 2005, Brouillat and Oltra 2012; Daniell et al. 2015
Participation	*No participation* (E.g. no dialogue; decisions about projects without user involvement)	*Less participation* (E.g. dialogue and consultations; no veto power)	*More participation* (E.g. collaboration; vote on projects)	*Participation* (E.g. coproduction of public services; vote on project decisions)	Bakker and Cook 2011; Ostrom 1996; Poocharoen and Ting 2015; Voorberg et al. 2015; Agarwal 2001
Outcome	*System less successful* (E.g. worse service provision)	*System slightly successful* (E.g. many constraints to service provision)	*System largely successful* (E.g. some constraints to service provision)	*System very successful* (E.g. same or better service provision)	Finger and Finon 2011

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3. Necessity

Condition(s)	*inclN*	*RoN*	*covN*
REGU	0.85	0.57	0.74
ECON	0.64	0.87	0.84
INFO	0.85	0.78	0.85
USER	0.73	0.70	0.75
PART	0.82	0.50	0.69
regu	0.30	0.93	0.77
econ	0.52	0.74	0.65
info	0.27	0.79	0.59
user	0.45	0.89	0.79
part	0.27	0.93	0.75
REGU+ECON	0.91	0.48	0.73
regu+INFO	0.94	0.60	0.80
REGU+INFO	0.97	0.37	0.73
REGU+PART	0.94	0.30	0.69
econ+INFO	0.94	0.45	0.74
ECON+INFO	0.94	0.75	0.86
econ+PART	0.91	0.29	0.67
INFO+user	0.91	0.62	0.79
INFO+USER	0.91	0.52	0.75
INFO+part	0.91	0.67	0.81

4. Truth table

Regulatory instruments (REGU)	*Economic incentives (ECON)*	*Information instruments (INFO)*	*User responsibility (USER)*	*Participation (PART)*	*Outcome (OUTC)*	*n*	*incl*	*PRI*	*Cases*
0	1	1	1	1	1	1	1.00	1.00	Onondaga
1	0	1	0	1	1	2	0.90	0.84	France, Hamburg
1	0	1	1	1	1	3	0.85	0.75	Barcelona, Berlin, Sweden

1	1	1	1	0	1	1	0.83	0.75	Japan
1	1	1	1	1	1	6	0.83	0.77	Ireland, Victoria, New South Wales, Ontario, San Francisco, Austria
0	0	0	0	0	0	1	0.75	0.51	UK
1	0	0	1	1	0	2	0.55	0.00	British Columbia, New Zealand
0	0	0	0	1	0	1	0.33	0.00	Poland

5. Parsimonious and complex solutions

Parsimonious solution

Path	*Solution*	*Single case coverage*	*Consistency*	*PRI*	*Raw coverage*	*Unique coverage*
1	**INFO**	Onondaga; Barcelona, Berlin, Sweden, France, Hamburg; Japan; Ireland, Victoria, New South Wales, Ontario, San Francisco, Austria	0.85	0.82	0.85	-
	=> OUTC					
				Solution consistency		0.85
				Solution PRI		0.82
				Solution coverage		0.85

Complex solution

Path	*Solution*	*Single case coverage*	*Consistency*	*PRI*	*Raw coverage*	*Unique coverage*
1	**REGU*econ*INFO*user*PART**	France; Hamburg	0.90	0.84	0.27	0.18
	+					
2	**regu*ECON*INFO*USER*PART**	Onondaga	1.00	1.00	0.18	0.09
	=> OUTC					
				Solution consistency		0.92
				Solution PRI		0.88
				Solution coverage		0.36

6. Solution formulas for level and issue clusters

Country level only

Path	*Solution*	*Single case coverage*	*Consistency*	*PRI*	*Raw coverage*	*Unique coverage*
1	**REGU*econ*INFO*PART**	France; Sweden	0.86	0.75	0.50	0.42
	+					
2	**REGU*ECON*INFO*USER*part**	Japan	1.00	1.00	0.17	0.09
	=> OUTC					
				Solution consistency		0.88
				Solution PRI		0.80
				Solution coverage		0.58

Regional level only

Path	*Solution*	*Single case coverage*	*Consistency*	*PRI*	*Raw coverage*	*Unique coverage*
1	**ECON* INFO*USER*PART**	Ontario, Onondaga, Vitoria, New South Wales	0.89	0.86	0.80	-
	=> OUTC					
				Solution consistency		0.89
				Solution PRI		0.86
				Solution coverage		0.80

City level only

All truth table configurations are used (no negative outcomes): no solution.

Wastewater technology only

Path	*Solution*	*Single case coverage*	*Consistency*	*PRI*	*Raw coverage*	*Unique coverage*
1	**REGU*INFO*user*PART**	France	0.86	0.67	0.54	-
	=> OUTC					
				Solution consistency		0.86
				Solution PRI		0.67
				Solution coverage		0.54

Water reuse only

All truth table configurations are used (no negative outcomes): no solution.

Rainwater harvesting only

Path	*Solution*	*Single case coverage*	*Consistency*	*PRI*	*Raw coverage*	*Unique coverage*
1	**part**	UK	0.75	0.67	0.27	0.18
	+					
2	**REGU*INFO*USER**	Berlin, Barcelona	1.00	1.00	0.46	0.19
	+					
3	**ECON*INFO*USER**	Onondaga	1.00	1.00	0.36	0.09
	=> OUTC					
					Solution consistency	0.89
					Solution PRI	0.86
					Solution coverage	0.73

7. Calibrated dataset, prior to QCA analysis

Case	Regulatory instruments	Economic incentives	Information instruments	User responsibility	Participation	Outcome
Japan	1	0.67	0.67	0.67	0.33	0.67
Ireland	1	0.67	0.67	1	1	0
Vitoria	1	1	0.67	0.67	0.67	1
New South Wales	0.67	1	1	0.67	1	0.67
British Columbia	1	0.33	0.33	0.67	0.67	0
Ontario	0.67	0.67	0.67	0.67	0.67	0.67
San Francisco	1	1	0.67	0.67	1	1
Onondaga	0.33	1	1	0.67	1	1
Barcelona Metro	1	0.33	0.67	1	1	0.67
UK	0.33	0	0	0.33	0	0.67
Berlin	0.67	0.33	1	0.67	0.67	1
Sweden	1	0.33	0.67	0.67	1	0.67
Poland	0	0	0	0	0.67	0
New Zealand	0.67	0.33	0	1	1	0.33
Austria	0.67	0.67	1	0.67	1	1
France	0.67	0	1	0.33	0.67	0.67

Hamburg	1	0	1	0.33	0.67	1

8. Expert interviews

Interviewees	Date	Location	Duration	Topics
Expert 1	6 March 2018	Meeting at Eawag, Dübendorf (Switzerland)	Ca. 1h	- *Talking about decentralization in the Australian water sector* - *Identifying potentially relevant case studies*
Expert 2	12 June 2018	Meeting at Eawag, Dübendorf (Switzerland)	Ca. 1h	- *Discussing the Japanese case*
Expert 3	21 February 2019	Meeting at Eawag, Dübendorf (Switzerland)	Ca. 1h	- *Discussing the Sydney and Melbourne case study* - *Identifying differences/ similarities between the two Australian cases* - *Learning about the Aquavero project*
Expert 4	13 March 2019	Skype conversation	Ca. 1h	- *Clarifying open questions about the Irish case*
Expert 5	11 June 2019	Meeting at University of British Columbia, Vancouver (Canada)	Ca. 1 ½ h	- *Talking about the decentralized wastewater systems in British Columbia* - *Discussing trends* - *Analyzing specifics compared to the rest of Canada*
Expert 6	11 June 2019	Meeting at University of British Columbia, Vancouver (Canada	Ca. 45 min.	- *Talking about the potential of decentralized wastewater systems in British Columbia*
Expert 7	13 June 2019	Meeting at University of British Columbia, Vancouver (Canada	Ca. 1h	- *Discussing the Vancouver Islands as specific case for British Columbia*
Expert 8	30 June 2019	Email exchange		- *Clarifying open questions about the Japanese case*