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Corporate Networks in Global Regimes and Their Implications for Sustainability Transitions

An Analysis of the Global Water Sector

by

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Abstract Sustainability transition research investigates why the necessary change towards more sustainable patterns of consumption and production has not yet been achieved and how it can be accelerated. Taking into account the complexity of the globalised dynamics underlying today's sustainability challenges, it has been suggested that the existence of global regimes limits the possibilities for change, as they lead to rigidity and path dependency in socio-technical systems. By asking the research question of *how corporate network structures influence the transformative capacity of a global regime*, this thesis aims to shed light on the role of actor networks within these global regimes. To this end, a case study of the global water sector is conducted, characterising its global regime structure by analysing the subsidiary network of the most influential water companies using Social Network Analysis. In doing so, a strong global regime is revealed in which a hierarchical international actor network diffuses dominant rationalities across the globe, weakening the water sector's capacity for transformation. By identifying regions that are both unsuitable and conducive to more sustainable alternatives, this thesis not only contributes to the theoretical and empirical understanding of global regimes, but also provides insights into where, in which countries and at which scales, policy efforts are most effective to transform unsustainable regimes.

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Acronyms

GPNs . . . . global production networks

GVCs . . . . global value chains

INGOs . . . . international non-governmental organisations

MLP . . . . Multi-Level-Perspective

MNCs . . . . multinational corporations

SNA . . . . Social Network Analysis

1 Introduction

Humanity has entered the century of the Anthropocene (Johnson, Lema, & Villumsen, 2017; Rockström et al., 2009). The fact that humans are the main driver of change to the Earth system has led to the emergence of "grand challenges" and the risk of humanity overstepping planetary boundaries (Johnson, Lema, & Villumsen, 2017; Rockström et al., 2009).[1] Having already crossed three out of nine, society is now about transgressing the others and leaving the "safe operating space for humanity" (Rockström et al., 2009). These developments have resulted in broad consensus that society's production and consumption patterns must fundamentally change to not undermine the planet's carrying capacity (Bauer & Fuenfschilling, 2019). However, efforts to move society towards more sustainable behaviours often face barriers to change, such as sunk investments, entrenched user practices and existing regulations resulting from strong path dependencies and "lock-in" mechanisms in so-called socio-technical systems (Geels, 2019; Markard, Raven, & Truffer, 2012). With the notion of socio-technical systems, economic sectors have been conceptualised as structures which consist of highly interrelated elements such as actors, institutions, technology, and knowledge (Markard, Raven, & Truffer, 2012). These socio-technical systems are usually characterized by high stability, which is due to the existence of socio-technical regimes (Coenen & Truffer, 2012; Miörner & Binz, 2020). Here, formal and informal rules that have co-evolved with a sector's technology favour incremental changes that follow traditional development paths by creating path dependencies and "lock-in" mechanisms (Markard, Raven, & Truffer, 2012; Miörner & Binz, 2020).

Since incremental changes have proven insufficient to address the "grand challenges" (Markard, Raven, & Truffer, 2012), the sustainability transitions research field examines socio-technical systems with the objective of guiding policy on how to accelerate the shift to more sustainable systems (Smith, Voß, & Grin, 2010; Truffer & Coenen, 2012). However, the neglect of space in transformation processes, and thus the failure to account for the globalized nature of the economy and sustainability challenges, has left many barriers to sustainability transitions unexplained (Coenen, Benneworth, & Truffer, 2012; Coenen & Truffer, 2012; Markard, Raven, & Truffer, 2012). Among others, established frameworks can neither explain the globalisation of technology development or diffusion, nor why similar socio-technical systems around the world face the same sustainability challenges despite different regional contexts (Fuenfschilling & Binz, 2018; Truffer & Coenen, 2012). Likewise, current research does not take into account that policy approaches to the same sustainability challenges necessarily depend on regional preconditions and must therefore vary across regions (Bauer & Fuenfschilling, 2019; Truffer & Coenen, 2012).

To address these shortcomings, Fuenfschilling and Binz (2018), starting from the observation that socio-technical regimes acquire validity beyond the national context, developed the concept of global socio-technical regimes that takes into account the dynamics within regimes and their multiscalar character. Global regimes influence the dynamics of sustainability transitions across national boundaries through transnational actor networks and dominant rules which have been institutionalized into international norms, practices and standards (Fuenfschilling & Binz, 2018). While this multiscalar conceptualisation of regime structures explains to some extent why similar solutions are influential in different contexts, major research gaps remain, especially concerning the identification of actor structures within regimes. Whereas it is clear that network actors in socio-technical systems are highly involved in creat-

[1] According to Johnson et al. (2017, p. 2) these challenges include: "[...] Climate change, demographic change, exploitation of global commons [...], food security, poverty and increasing inequality."

ing, maintaining and disrupting regime rules, it is not known which actors have the greatest influence on these processes and why (Fuenfschilling & Binz, 2018). In this context, it has been argued that companies and in particular multinational corporations (MNCs) play a key role in the diffusion of regime rationalities through their financial resources, geographical reach, prestige and engagement in institutional work (Fuenfschilling & Binz, 2018; Köhler et al., 2019). Further, it has been suggested that corporate networks of MNCs resist sustainability transitions through their efforts to replicate and reinforce traditional regime solutions (Bauer & Fuenfschilling, 2019). In any case, policies can only intervene effectively in a global regime once the regime actors as well as their networks have been identified and analysed in detail (Fuenfschilling & Binz, 2018). The aim of this thesis is therefore to contribute to the theoretical and empirical understanding of global regimes through an analysis of corporate structures within global regimes. An analysis of these actor networks is expected to provide insights into the dynamics through which regime rules are diffused, reproduced or replaced across the world, with important implications for sustainability transitions. To do so, this thesis will apply the conceptual lens of a global regime to examine the opaque corporate structures of MNCs and ultimately explore the following research question:

How do corporate network structures influence the transformative capacity of a global regime?

To answer this question, a case study of an economic sector using Social Network Analysis (SNA) is proposed. Since especially infrastructure sectors face serious problems such as resource scarcity, climate change and resource degradation, the global water sector is chosen as a case study (Fuenfschilling & Truffer, 2014). The sector is particularly relevant in that it faces sustainability challenges with environmental, economic and social costs, while at the same time being key to sustainability goals such as providing safe water and sanitation and protecting aquatic ecosystems (Lieberherr & Fuenfschilling, 2016; UN, 2020). For the purpose of this thesis, the water sector will further serve as an extreme case, as its strong global regime structures offer promising insights for sustainability transitions (Miörner & Binz, 2020). It is remarkable that alternatives to traditional centralised large-scale infrastructure exist but do not diffuse, despite the obvious shortcomings of traditional solutions (Fuenfschilling & Binz, 2018; Kiparsky et al., 2013). Emblematic is the failed transition in China's wastewater sector, where, despite the existence of an alternative technology industry, traditional Western infrastructure was implemented, in part because of the dominant role of MNCs in the industry (Fuenfschilling & Binz, 2018). Despite these findings on the relevance and role of MNCs in the water sector, the global corporate network structures have not yet been the subject of systematic analyses.

It is expected that the mapping and subsequent analysis of private actor structures in global regimes will enable the study of global power structures and thus the design of appropriate policy strategies to counter the resistance of established regime actors to sustainability transitions. It will also help to discern where, in which countries or at which spatial scales, policy would have to intervene to transform existing regime structures. To this end, this thesis will identify the most influential players in the global water sector using the Orbis database (Bureau van Dijk, 2021). The analysis is then carried out by visualizing and characterizing the relationships between headquarters and subsidiaries, extended by a regional analysis of the companies' spatial strategies. Spatial interlocks between companies are then identified, as well as the locations of consulting and engineering firms that also operate in the water sector.

This analysis represents an important step in deriving globally coordinated policies, as with the help of the SNA, both the overall regime structure and the position of individual actors in the network can be characterised and thereby points for policy interventions identified. For this purpose, both regions where established regimes dominate and those where global regime structures do not yet exist are of interest. Thus, this analysis will be of utmost relevance as the establishment of sustainable infrastructure solutions is central to achieving global sustainability (Binz et al., 2012).

The thesis will proceed as follows: Section 2 introduces the research field of sustainability transitions and the literature on the geography of sustainability transitions in a literature review before presenting the case study of the global water sector. Section 3 outlines the origins and foundations of the methodological framework. Subsequently, section 4 explains the derivation of the data on the most influential actors in the global water sector. Section 5 addresses the results of the analysis in three parts, which are then discussed in section 6 with an explicit focus on policy implications. Section 7 concludes.

2 Literature Review

The literature on sustainability transitions provides valuable inputs for understanding the encompassing dynamics of transforming economies and societies by developing and employing frameworks for analysing established socio-technical structures as barriers towards new modes of production and consumption (Bauer & Fuenfschilling, 2019; Truffer & Coenen, 2012). As various actors from numerous disciplines are involved in the sustainability transitions research community, the research field is characterised by a high degree of complexity (Markard, Raven, & Truffer, 2012). An overview of research on sustainability transitions in terms of its emergence, development and current trends is therefore provided in the following. The case study of the water sector is introduced subsequently.

2.1 Sustainability Transitions

Research on sustainability transitions has its roots in the academic field of socio-technical transition research, which emerged in the early 2000s in the field of innovation studies (Geels, 2019). In innovation studies, concepts such as the technological regime were first introduced by Nelson and Winter (1982), who used the term to denote dominant beliefs and ideas about successful technological designs to account for incremental developments along established innovation paths. The social component was later added by Rip and Kemp (1998) who emphasized the embeddedness of technology in society and thus established socio-technical system thinking. By combining ideas from evolutionary economics and the sociology of technology, the authors presented technologies as "configurations that work", therefore not only including technological components but also people, processes and artefacts (Rip & Kemp, 1998, p. 387).

A central component of these socio-technical systems are socio-technical regimes which constitute the "rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems [and are] embedded in institutions and infrastructures" (Rip & Kemp, 1998, p. 388). Put in another way by Geels (2002; 2007), the regime consists of semi-coherent rules which are regulative (regulations, standards), normative (values, norms) and cognitive (beliefs, problem definitions principles) in nature and impose a logic for change favoring incremental rather than radical developments. As these rules have co-evolved with a particular technology, they have a highly stabilising effect on the current socio-technological system resulting in path dependencies due to "lock-in" mechanisms (Coenen & Truffer, 2012).

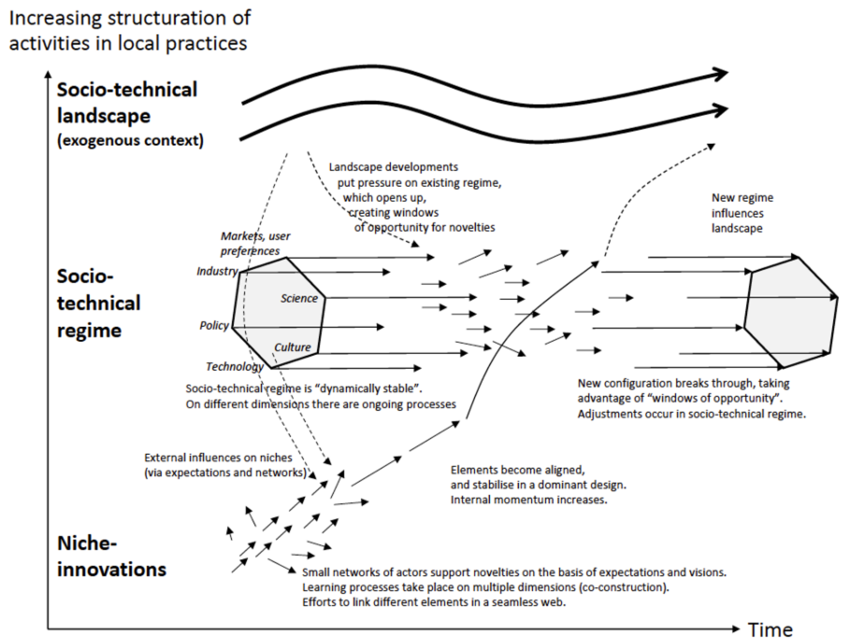
Only when these "lock-in" mechanisms are overcome and a "fundamental social, technological, institutional, economic change from one societal regime [...] to another" takes place, a transition has been achieved (Hölscher, Wittmayer, & Loorbach, 2018, p. 1). Transitions include therefore not only changes in technologies but also in user practices, discourses policies and institutions (Coenen, Benneworth, & Truffer, 2012). Sustainability transitions differ from "conventional" transitions in the sense, that guidance, governance as well as normative values often play a particular role (Smith, Stirling, & Berkhout, 2005). Hence they can be defined as "long-term, multi-dimensional and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard, Raven, & Truffer, 2012, p. 956).

Next to systemic approaches such as strategic niche management, transition management and technological innovation systems, the Multi-Level-Perspective (MLP) has developed as the analytically dominant framework in studying sustainable system transformations (Coenen, Benneworth, & Truffer, 2012). As the MLP is concerned with deep sectoral transformation (Coenen, Benneworth, & Truffer, 2012), it is identified as the relevant concept for this thesis.

2.1.1 Multi-Level-Perspective

Building on the earlier work of Rip and Kemp (1998) the MLP has been developed by Geels (2002) to take account of historical transitions towards new socio-technical systems. More recently, it has also found extensive application in sustainability transition research due to its ability to engage with the dynamics of the large socio-technical systems that are subject to current sustainability challenges (Smith, Voß, & Grin, 2010).

Following the illustration of the MLP in Figure 1, transitions are the result of a dynamic interplay between three analytical levels: the niche, the socio-technical regime and a socio-technical landscape. While radical innovations are developed in the protected space of a niche, the institutional structure of the established regime is responsible for path dependencies and thus rather incremental innovations. A transition takes place when a radical innovation successfully destabilises the established socio-technical regime resulting in a new socio-technical configuration within the regime. Exogenous pressure from the socio-technical landscape, the deep structure in which a socio-technical system is embedded, can encourage transitions as it might lead to tensions within the established regime and thus to windows of opportunity for the breakthrough of niche innovations.[2] Early applications of the MLP include Geels' (2002) account of the historical transition from sailing ships to steamships and his study of the Dutch hygienic transition from cesspools to sewers, in which he elaborated the role of regime dynamics for socio-technical transitions (Geels, 2006).



Note: Based on Geels and Schot (2007, p. 401).

Figure 1 MLP on transitions.

[2]Changes in heterogeneous factors such as economic growth, oil prices or the effects of climate change may alter the socio-technical landscape.

Suggesting that also incumbent regime actors can enact socio-technical transitions, Geels (2006) proposes a regime transformation pathway as an alternative to the former technological substitution. Here, a gradual transition can take place, when regime actors change their perceptions and beliefs and thus change the regulative, normative and cognitive rules of the system.[3] However, regime actors and particularly incumbent firms often oppose sustainability transitions and make use of several resistance strategies to guarantee the persistence of the current socio-technical regime (Geels, 2019). These include information and framing, financial, lobbying and organized pressure as well as confrontational strategies. In contrast, incumbent firms, stimulated by financial opportunities, can also accelerate the transition to sustainability by aligning their financial assets, technological capacities and policy capabilities with the emerging socio-technical configuration (Geels, 2019).

While the MLP has been acclaimed for adequately addressing the societal embeddedness of socio-technical systems (Coenen, Benneworth, & Truffer, 2012), it has nevertheless been subject to considerable criticism. Geels and Schot (2007) have countered first criticisms regarding the lack of precision at the empirical and analytical levels, the neglect of agency and the excessive focus on technological niches by developing a typology based on variation in the timing and nature of multi-level interactions. Further criticisms, which are of particular relevance for this thesis, are, however, of a more fundamental nature.

First, the MLP has been criticized, among others by Genus and Coles (2008), for a missing conceptual clarity and analysis of the regime level. Whereas institutional contradictions and tensions can occur in reality, the conceptualization of the regime has been "monolithic" and "homogeneous" within the MLP and its empirical applications (Fuenfschilling & Truffer, 2014).[4] The second criticism concerns the missing treatment of space and scale within the MLP (Smith, Voß, & Grin, 2010), which is highly inappropriate considering the globalised world economy and the global dimension of sustainability challenges (Truffer & Coenen, 2012). In most studies, the geography of sustainability transitions has only been addressed indirectly and implicitly, since most empirical studies focus on individual countries and thus assume that transitions would take place at the national level (Truffer & Coenen, 2012). Therefore, these studies are unable to take into account the role of transnational actors and relationships in transition processes (Truffer, Murphy, & Raven, 2015), resulting in deficits concerning their explanatory value and ability for policy advice (Truffer & Coenen, 2012). With regard to socio-technical regimes, there has been the tendency to assume that the regime level would resemble the national scale (Markard, Raven, & Truffer, 2012; Smith, Voß, & Grin, 2010). This is not only misleading in the direction that MLP levels are not geographical but rather reflect the socio-cognitive development of the respective actors and institutions (Coenen & Truffer, 2012), but also neglects that also state actors see themselves confronted with processes beyond their jurisdiction in their wish for a sustainable transformation (Smith, Voß, & Grin, 2010).[5] Thus, an unpacking of spatial boundaries in case studies becomes as important as acknowledging place-specific impacts in order to account for transition processes in a globalised world (Coenen & Truffer, 2012; Markard, Raven, & Truffer, 2012).

[3]In the same vein, Berkhout et al. (2004) suggest four alternative transition pathways including the "endogenous renewal" and "reorientation of trajectories" of the regime.

[4]An alternative conceptualization of the socio-technical regime by Fuenfschilling and Truffer (2014) will be introduced in section 2.2.1. In this section the theoretical framework of a global socio-technical regime will be presented.

[5]These processes can include, for example, the takeover of local infrastructure by MNCs (Smith, Voß, & Grin, 2010), so that the governance of transitions in this area becomes a collaborative act of public and private actors with differing interests (Hansen & Coenen, 2015).

2.2 Geography of Sustainability Transitions

The above critique has given rise to a new field of research that is primarily concerned with explaining the spatial heterogeneity of transition dynamics, the territorial embeddedness of established regimes and the multiscalar nature of the elements that form the socio-technical system (Murphy, 2015). Based on an understanding of place-specific factors such as institutional frameworks, local cultures, infrastructures and resource endowments, as well as social networks, the aim is to identify factors that promote or impede sustainability transitions (Köhler et al., 2019). The foundation and research agenda of the new field of the geography of sustainability transitions is outlined in contributions such as from Truffer and Coenen (2012), Coenen and Truffer (2012) and Coenen et al. (2012).

Transitions are influenced by the territorial contexts in which socio-technical systems are embedded, as well as by the multiscalar relationships of their heterogeneous elements located in different places or at different scales (Murphy, 2015). Hence, two topics are central to the research field, namely institutional embeddedness and the multiscalarity of transition processes (Coenen, Benneworth, & Truffer, 2012). While institutional embeddedness refers to the specific conditions in particular places, cities or nations that favour or hinder transformation processes (Truffer, Murphy, & Raven, 2015), the issue of multiscalarity is of considerable interest to this thesis as it refers to the importance of local nodes and global connections for transformation processes (Coenen, Benneworth, & Truffer, 2012).

The need for paying attention to multiscalarity is caused by the expansion of markets, financial infrastructures and knowledge networks across scales (Truffer & Coenen, 2012). Relational economic geography suggests that in a globalised world, actors construct scales in a way that suits them best, so that, for example, corporate structures extend around the globe (Coenen, Benneworth, & Truffer, 2012). Therefore, a study of transitional spaces must not be limited to administrative boundaries (Truffer & Coenen, 2012). Accepting that space is socially constructed and manifests itself in networks across spatial scales enables the understanding of complex issues such as the promotion of unsuitable infrastructure solutions by industrialized countries and subsequent adoption by developing countries (Truffer & Coenen, 2012).[6] A multiscalar conceptualisation of the analytical levels of MLP will therefore be informative about how the power of actors in sustainability transitions is shaped by their relationships in networks across multiple scales (Coenen & Truffer, 2012).

Some progress in this direction has already been made, albeit only at the analytical level of the niche. Wieczorek et al. (2015), for example, illustrate the importance of transnational linkages for sustainability experiments with a case study of 65 photovoltaic experiments in India. Furthermore, Sengers and Raven (2015) develop a spatially sensitive model of niche development which they then apply to the rapid diffusion of Bus Rapid Transit models around the world. In doing so, the authors highlight the embeddedness of socio-technical configurations in specific geographical contexts while emphasizing the importance of global networks for knowledge exchange.

Despite these developments, the current discourse still favours empirical studies on spatial variations of transitions with a focus on urban transitions and transitions in developing countries (Binz et al., 2020). The need to reconceptualise the foundations of research on sustainability transitions has been largely neglected (Binz et al., 2020), with most studies only adding spatial sensitivity to the traditional frameworks

[6] The term "developing country" does not represent a normative valuation, neither here nor in the further course of the work. In line with Hansen et al. (2018) it is applied to highlight commonalities which differentiate the relevant countries from the so-called developed countries.

(Hansen & Coenen, 2015). In particular, regime dynamics have not been analysed due to a focus on niche development approaches making this topic an empirically and theoretically understudied field of research (Hansen & Coenen, 2015). However, since the regime is assumed to have the strongest influence on the trajectory of a socio-technical system, it is fundamental to also include regime dynamics in the analysis in order to understand transition dynamics in their entirety (Fuenfschilling & Binz, 2018). A spatially nuanced regime conceptualisation is expected to provide insights into new potential sources of innovation, so far unknown actor types and constellations, and regime-niche interactions in transformation processes (Fuenfschilling & Binz, 2018).

2.2.1 The Global Socio-Technical Regime

In a rather early study in the field of geography of sustainability studies, Späth and Rohracher (2012) aptly summarise what is misleading in the current conceptualisation of socio-technical regimes. By analysing the impact of local energy transition initiatives on the global energy transition, they highlight that regimes not only vary across spatial contexts, but are also characterised by internal inconsistencies, irregularities and conflicts with considerable implications for sustainability transitions. Fuenfschilling and Binz (2018) address exactly these considerations with their proposal of a global socio-technical regime.

With their conceptualisation, the authors aim to answer the question of why, despite different preconditions in certain regions, the trajectories of transitions are similar. Combining insights from sociology and human geography, Fuenfschilling and Binz (2018) propose that socio-technical systems develop sector-specific institutional rationalities that are diffused globally through international networks. The concept of institutional rationalities has been originally developed by Fuenfschilling and Truffer (2014) who invoke that the dominant rules within a socio-technical system are institutional, i.e. rather cultural-cognitive than material, in their nature.[7] As a consequence a socio-technical regime can be described as a dominant rationality which has been institutionalised into practices, routines, technologies and standards. Since these rationalities are socially constructed, they are subject to disputes and conflicts and different rationalities can prevail within a regime (Fuenfschilling & Truffer, 2014). Sociology, particularly the new institutionalism theory, now proposes that these rationalities can influence transitions beyond their origins, as isomorphism leads to an increasing similarity of actors and practices across the world (Fuenfschilling & Binz, 2018). Fuenfschilling and Binz (2018) complement this idea with the economic-geographic notion of global value chains (GVCs) and global production networks (GPNs), which describe the mechanisms through which regime rationalities spread to particular places in the world. While both frameworks account for the "nexus of interconnected function, operations, and transactions through which a particular product or service is produced, distributed and consumed" (Coe, Dicken, & Hess, 2008, p. 272), the GPN approach goes beyond the GVC concept (Coe et al., 2004). With its strong emphasis on networks, the GPN encompasses all relevant actors and institutions in the global economy that are interconnected and, thus, integrate geographical scales (Coe, Dicken, & Hess, 2008). Whereas different actors are involved in the diffusion of knowledge, technologies and investments across the network, MNCs are considered the backbone of any GPN structure due to their enormous organisational capacity and geographical reach (Fuenfschilling & Binz, 2018). This is of importance for the degree of hierarchy within the global production network, which

[7] Fuenfschilling and Truffer (2014) use the notion of institutional logics to describe regime rationalities.

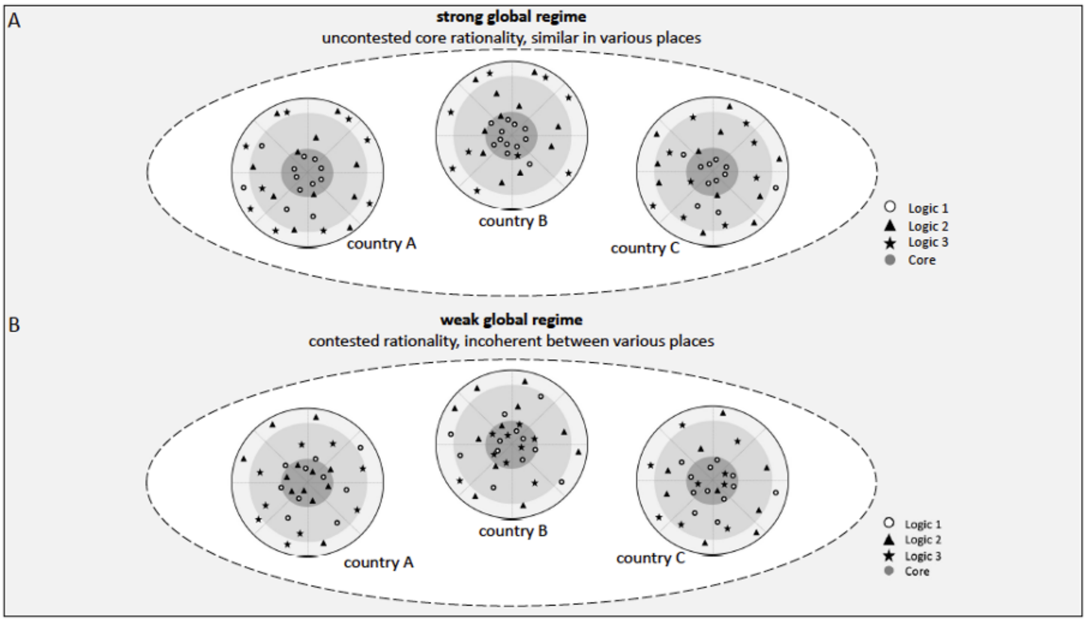
in turn is decisive for the extent to which regime rationalities will spread more or less easily to different regions.[8]

With these conceptual elaborations in mind, Fuenfschilling and Binz (2018, p. 739) define a global socio-technical regime as "the dominant institutional rationality in a socio-technical system, which depicts a structural pattern between actors, institutions and technologies that has reached validity beyond specific contexts, and which is diffused through international networks." The global socio-technical regime is, therefore, a semi-coherent, multiscalar, institutional rationality which is influenced by different actors and subject to contestation (Fuenfschilling & Binz, 2018). A global regime can exert different degrees of institutional pressure (normative, cultural-cognitive or regulatory) depending on its level of structuration and institutionalization (Fuenfschilling & Binz, 2018; Fuenfschilling & Truffer, 2014).[9] While tension between global and local regime rationalities or a distance from the regime through non-participation in the respective GPN can lead to spatial variations in socio-technical systems, a socio-technical regime will be strongest when its dominant rationality has diffused into various regions characterised by diverse preconditions (Figure 2) (Fuenfschilling & Binz, 2018). Similarly, regimes with mature and hierarchical GPNs are expected to be exceptionally strong due to resource-rich key actors and historically developed and widespread rationalities. In particular, MNCs are expected to play a dominant role in this sense due to their geographical reach, resource endowment and prestige, which enables them to spread rationalities to the most peripheral actors in a production network (Fuenfschilling & Binz, 2018). Similar to MNCs, the so-called "generalised others", which include professional organisations, INGOs, consultancies and policy experts, are assumed to influence the flow of rationalities throughout the regime through their high definitional power. Together with the MNCs, these actors are believed to be responsible for the formulation and diffusion of the regime's rationalities, while the peripheral network actors are in a captive position, reproducing the dominant rationalities through mimetic pressure. Therefore, actors in a global regime have different capacities to steer the trajectory of the regime, with the MNCs and the "generalised others" likely to be the most powerful in maintaining or changing rationalities (Fuenfschilling & Binz, 2018).

The existence of such a global socio-technical regime then explains the surprising similarity of various socio-technical systems in different world regions with important implications for sustainability transitions. While the existence of a strong global regime is likely to prevent a transformation to sustainability in most cases, its influence and reach could also provide a pathway for rapid diffusion of sustainable innovations once they have found their way into the regime. A recognition and analysis of these global regime structures thus becomes essential for deriving appropriate and effective transition policies (Fuenfschilling & Binz, 2018).

[8] The degree of hierarchy is according to Gereffi et al. (2005) dependent on three factors: The complexity of transactions and ability to codify these as well as the capabilities of the suppliers.

[9] This depends on various immaterial factors such as the diffusion, duration of existence and coherence of rationalities, but also on the materialisation of the regime in binding structures (Fuenfschilling & Binz, 2018).



Note: Adapted from Fuenfschilling and Binz (2018, p. 741).

Figure 2 Comparison of a strong and weak global regime.

As the global socio-technical regime constitutes a very recent contribution, it has only been applied in a limited number of studies. These include Fuenfschilling and Binz' (2018) illustration of the unsuccessful transition in the Chinese wastewater sector towards more sustainable alternatives. Here, the dominant rationality of the global socio-technical regime of the water sector, supported by a coalition of multinational corporations, supranational organisations, development banks and international consultancies, was able to undermine sustainable niche initiatives. Another study by Bauer and Fuenfschilling (2019) analyses the interplay of local sustainability initiatives and global regimes by means of a case study of the chemical industry in Sweden. The authors identify the dominance of MNCs in the Swedish chemical industry as responsible for the permanent entrenchment of the prevailing unsustainable regime. Bauer and Fuenfschilling (2019) conclude that an analysis of a sector's locally embedded and globally institutionalized regime will be conducive for designing effective transition policies. Furthermore, a conceptual contribution is provided by Miörner and Binz (2020) who propose a multiscalar perspective towards transition trajectories to account for conceptual tension between (global) regime structures and their manifestation in local or regional contexts. By analysing the case of technology standardisation in the wastewater sector, the authors show that actors can directly institutionalise an emerging rationality at the level of global regimes through re-scaling initiatives.

While Fuenfschilling and Binz (2018) called for the concrete analysis of regime structures for specific sectors in their first contribution, present studies did not go beyond acknowledging the existence of global socio-technical regimes. Major research gaps therefore remain, especially with regard to the actor structures within global regimes. However, identifying established regime actors without setting spatial boundaries is not only crucial for recognising global barriers to but also windows of opportunity for sustainability transitions. According to Fuenfschilling and Binz (2018), a mapping of regime structures including the visualisation of global actor structures and a subsequent analysis using SNA could be an effective means to this end. Such an analysis is expected to provide insights into the influence of different regime actors on the dynamics through which regime rationalities are created, maintained or changed.

As outlined above, the economic geography literature implies a particular importance of MNCs for regime strength. For this reason, this thesis will focus on the impact of global power structures resulting from different corporate network configurations on sustainability transitions. The identification of spatial network configurations and their implications for the transformative capacity of a global regime, is expected to further contribute to the theoretical conceptualisation of the regime. In particular, network configurations will be examined in terms of their dominant actors and spatial extent, in order to ultimately identify where policy should intervene to most effectively combat resistance from incumbents and accelerate sustainability transitions. To answer the main research question of

How do corporate network structures influence the transformative capacity of a global regime?

the following sub-research questions were formulated:

- SQ: What are the implications of different corporate network configurations for the dynamics within a global socio-technical regime?
  - To what extent does the resulting corporate network spread to all world regions (strong regime) or does it exist only in a selected subset of world regions (weak regime)?
  - To what extent is the resulting corporate network structure hierarchical (strong regime) or scale-free (weak regime)?
- SQ: Which policy implications result from the identified network configurations in order to achieve sustainable infrastructure transformations?
  - Where, in which countries or at which scales, would policy interventions have the strongest effect?

In general, spatial network analyses of the corporate structure of large MNCs are rare (Verbeek, 2019), and have not been undertaken against the background of a global socio-technical regime. However, they are becoming increasingly popular and recent examples include Wall, Burger and Van der Knaap's (2011) analysis of ownership relations between the Global Fortune Top 100 MNCs and their subsidiaries to estimate the spatial distribution of global corporate activity. In addition, Wall and Van der Knaap (2011) examined the same data set to investigate the global and regional interdependencies of the top 100 MNCs. Further examples of spatial network analyses include Yang and Dong's (2016) study of the spatial strategies of the biggest petroleum corporations using headquarter and subsidiary data and Verbeek's (2019) examination of headquarter-subsidiary links in the petrochemical industry. One of the most recent contributions is provided by Verbeek and Mah (2020), in which the authors uncover patterns of integration and isolation in the petrochemical industry by analysing, among other things, spatial interlocks of corporate networks. Although these studies are situated in research strands other than sustainability transitions, such as the world city literature, they provide valuable implications for this thesis through the incorporation of insightful elements of SNA. Several concepts of these studies are therefore taken up again in section 3.2 and used for the analysis of the case study, which is presented in the following section.

2.3 Case Study: The Global Water Sector

Nowadays, especially infrastructure and utility sectors see themselves confronted with the grand challenges and experience strong transformation pressures (Fuenfschilling & Truffer, 2014). However, the transformation of infrastructure systems towards more sustainable alternatives has only recently started to receive more attention in the literature, with most contributions focusing on energy and transport, while water, food and other systems have received less attention (Markard, 2011; Markard, Raven, & Truffer, 2012). As there is a growing awareness that the majority of infrastructure systems are intrinsically unsustainable and that a fundamental change through viable alternatives is needed (Loorbach, Frantzeskaki, & Thissen, 2011), the research focus should be on the transformation of entire infrastructures and the associated challenges.

In principle, infrastructure sectors can be considered as socio-technical systems, as they consist of a multitude of interconnected and interdependent actors, technologies, institutions and knowledge bases, making them of greatest interest for sustainability transition research (Markard, Raven, & Truffer, 2012). Infrastructure sectors differ from other sectors in the sense that they have developed over a long period, which has made them highly complex systems interwoven with economic, institutional and organisational structures (Markard, 2011). Together with the focus on continuous service provision, the socio-technical systems of infrastructure systems are therefore characterised by surprisingly similar features, such as high systematisation, high capital intensity and asset longevity (Markard, 2011; Truffer et al., 2013). Precisely because of these characteristics, infrastructure sectors show a preference for well-proven incremental innovations and tend to reject radical innovations, which subjects them to inertia and makes the breakthrough of sustainable alternatives particularly difficult (Truffer et al., 2013).

The choice of the water sector as the infrastructure sector of interest follows the principle of information-driven selection, where a maximum amount of information is to be extracted from smaller samples or a single case (Flyvbjerg, 2006). Here, the water sector serves as an extreme case, as the sector is expected to be exceptional informative for investigating the conceptual framework of a global socio-technical regime. As will be explained in this section, certain characteristics of the global water sector have contributed to the development of one of the strongest existing global socio-technical regimes alongside that of the oil and gas sector. The resulting high conformity of solutions offered by the sector makes the water sector particularly problematic for sustainability transformations, which is why the analysis is expected to provide valuable insights.

For the purpose of this thesis, the "water sector is defined to include all aspects of water production, treatment and supply, up to and including the operation of sewerage systems and wastewater plants" (Lesch, 2021, p. 2). As with infrastructure systems in general, the water sector is characterised by a very strong interconnectedness between its technological and institutional elements, which exposes transition initiatives to a particular challenge and makes institutional innovations as important as technological ones (Kiparsky et al., 2013). Despite different regional conditions, the water sectors of industrialised countries are very similar in terms of key players, technologies, organisation and financing schemes (Lieberherr & Fuenfschilling, 2016). Fuenfschilling and Truffer (2014) attribute this similarity to the existence of a dominant institutional rationality, the "hydraulic logic", in the sector's socio-technical system (Figure 3). This rationality emerged in the 20$^{\text{th}}$ century, when the missions of meeting the water needs of all citizens and ensuring the security of supply prevailed, which was adressed by the construction of large-scale infrastructure in the form of dams, aqueducts, pipelines and treatment plants (Fuenfschilling & Truffer, 2014; Gleick, 2003). Together with the unique characteristics of the water sector, presented in Table 1, this led to a centralized network infrastructure operated by public utilities under state supervision as the most common solution (Fuenfschilling & Truffer, 2014; Lieberherr & Fuenfschilling, 2016).

Table 1 Characteristics of the water sector.

Characteristics	
Large-scale technologies	Bulky, capital intensive, sunk costs, asset durability, economies of scale and scope → natural monopolies
High externalities	Public and environmental health → state intervention historically
Nature of the good	Essential, irreplaceable, natural resource, scarce, social equity concern → highly political and high regulation

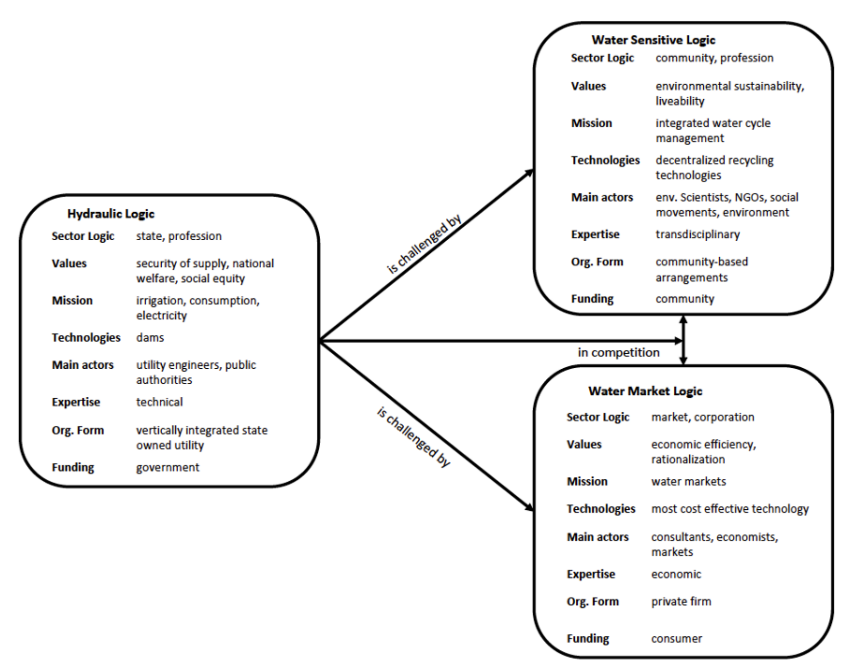
Note: Adapted from Lieberherr and Fuenfschilling (2016).

However, with the emergence of the neoliberal paradigm in the 1980s, a competing institutional rationality, the "market-based logic", emerged and the commodification of water became the new hegemonic idea (Figure 3) (Fuenfschilling & Truffer, 2014; Lieberherr & Fuenfschilling, 2016; Swyngedouw, Page, & Kaika, 2002). As commodification transformed water into a marketable commodity and subjected it to market principles (Swyngedouw, Page, & Kaika, 2002), public utilities were increasingly corporatized and privatised, with multinational companies and consultancies taking over the planning, implementation and operation of large-scale water projects (Fuenfschilling & Truffer, 2014). Economic efficiency replaced the value of a safe water supply and consumers became the financiers of the sector, just as technology decisions became subject to in-depth cost-benefit analyses and supply demand-calculations (Fuenfschilling & Truffer, 2014). In the following years, water operators expanded their business geographically and an oligopolistic structure of internationally active water multinationals emerged (Swyngedouw, Page, & Kaika, 2002). Nowadays, a handful of MNCs occupy dominant positions in the hierarchical GPN of the water sector, alongside actors such as private engineering firms, international development and investment banks and international non-governmental organisations (INGOs) (Fuenfschilling & Binz, 2018). As a result, the water sector is subject to a power asymmetry in which private actors are involved in important decision-making processes, whether through lobbying in international organisations such as the World Water Council or through the phenomenon of the "revolving door" (Heller, 2020; Pigeon et al., 2009). Ultimately, the ability of MNCs to provide entire cities with turnkey solutions for water and sanitation infrastructure has made them prominent and powerful players, and eventually gatekeepers for the adoption of innovations (Fuenfschilling & Binz, 2018; Lieberherr & Truffer, 2015; Swyngedouw, Page, & Kaika, 2002). As part of the global socio-technial regime's core, MNCs will therefore be of utmost importance for any transformation attempts in the water sector (Lieberherr & Truffer, 2015).

Irrespective of whether under the "hydraulic" or "market-based logic", the paradigm of large-scale sewage networks and centralized treatment plants operated by utilities has spread across the most diverse regions of the world (Miörner & Binz, 2020). While the traditional mode of provision certainly has its merits when it comes to providing clean water to a large number of citizens (Larsen et al., 2016), its suitability and also sustainability has increasingly been questioned. The construction and maintenance of the water sector's centralised infrastructure is not only associated with economic costs, but also with unforeseen social and environmental costs (Gleick, 2003; Lieberherr & Fuenfschilling, 2016). First of all, an ageing infrastructure in industrialised countries and the need to provide water and sanitation to citizens in developing countries place an extraordinarily high investment demand on society

(Gleick, 2003; Larsen et al., 2016). If this demand is to be met with conventional types of infrastructure, current estimates suggest that investments of over US$60 trillion would be required to achieve the goal of ”water and sanitation for all” (Larsen et al., 2016; UN, 2020). Secondly, high investment costs and a long planning horizon require long-term demand forecasts, which are increasingly difficult to prepare due to population growth and the onset of urbanisation, especially in developing countries (Gleick, 2003; Larsen et al., 2016). Weak institutions, the absence of secure tenure and rule of law make investment and thus the construction of large-scale water infrastructure in some developing countries additionally unattractive (Larsen et al., 2016). Finally, grid infrastructure that depends on large amounts of water increasingly promotes inefficient resource use, which is particularly inappropriate in water-scarce regions and in the face of climate change (Fuenfschilling & Binz, 2018; Larsen et al., 2016).

These considerations have led, among other things, to the emergence of a ”water-sensitive logic” with a focus on ecological sustainability and thus to alternative forms of service provision that rely on a decentralised organisation of the sector (Figure 3) (Fuenfschilling & Truffer, 2014). While solutions such as non-grid, small-grid and hybrid systems already exist that would be able to address the challenges mentioned above (Hoffmann et al., 2020), in practice implementation is rather slow (Kiparsky et al., 2013). Despite their advantages, such as the possibility of short-term installation and lower investment costs (Larsen et al., 2016), their application remains limited to model regions such as Beijing, San Francisco, Sydney, Hamburg and Bangalore (Hoffmann et al., 2020). The lack of application is particularly problematic for infrastructure development in developing countries, where the implementation of more sustainable solutions is of great importance to achieve global sustainability (Binz et al., 2012). Currently, however, developing countries seem to rely on centralised infrastructure solutions (Hoffmann et al., 2020; Larsen et al., 2016). Here, the already mentioned example of China is emblematic, which initially started to implement decentralised solutions for the development of its water infrastructure due to the country-specific conditions, but ultimately decided on traditional Western infrastructure solutions despite functional limitations (Fuenfschilling & Binz, 2018).



Note: Recreated based on Fuenfschilling and Truffer (2014, p. 779).

Figure 3 The different institutional logics in the water sector.

The above remarks point to the existence of a strong global socio-technical regime that stabilises and continuously reinforces the current system. Presumably due to the strength of the regime with its entrenched institutions and established actors, a transformation of the socio-technical system is not in sight despite changes in the valuation of water as a resource and technological advances in sustainable water management (Brown, 2008). In addition to technological development, a reform of all relevant institutional structures, therefore, becomes extremely necessary. This includes countering the strategies of incumbents who block transitions out of fear of the potentially disruptive innovations and the resulting challenges in transforming their service delivery and reorganising their value chain (Kiparsky et al., 2013; Truffer et al., 2013). After all, Swyngedouw, Page and Kaika (2002) note, powerful MNCs, in particular, contribute significantly to sustainability challenges through their focus on centralised water infrastructure. In fact, contrary to earlier expectations, commodification has not addressed environmental sustainability problems but has exacerbated them in addition to negative social impacts such as rising water prices and household disconnections (Larsen et al., 2016; Lieberherr & Fuenfschilling, 2016). According to the former Special Rapporteur on the human rights to safe drinking water and sanitation, Léo Heller (2020), the power of MCNs may even increase as the 2030 Agenda for Sustainable Development has created greater pressure for service delivery and thus private sector involvement. Indeed, privatisation of public utilities remains on the political agenda of several countries, especially in Eastern Europe and Asia (Heller, 2020). The possibility of large MNCs entering service provision, through contracts that suit them best, increases the geographical reach in which they can spread the prevailing regime rationality.

As has been illustrated above, the global water sector can be described as a "black box" with various actors and strong institutional rationalities which impede any effort toward a sustainable transition (Hoffmann et al., 2020). Unpacking this "black box" by analysing the geographical distribution and interdependencies within the global regime of the water sector will first and foremost improve researchers' and policy makers' understanding of the dynamics within the sector. Furthermore, determining the scope of action of the most powerful actors in the water sector enables the identification of points for political intervention and windows of opportunity. The idea is to identify regions where regime structures are highly prevalent as well as regions where no incumbent actors are currently active, with the ulterior motive that ultimately new actors will need to gain access to the supply chain in order to diffuse technological alternatives (Lieberherr & Truffer, 2015). This paper aims to do just that by revealing the spatial distribution of the largest private water MNCs based on headquarters-subsidiary data. The resulting networks will then be analysed using SNA. To this end, propositions based on the literature review are established in the following. These serve as a guidance for the analysis of the headquarter and subsidiary data.

2.3.1 Propositions

- P1: The corporate network of the most influential MNCs in the water sector is expected to be characterized by a strong hierarchy, with certain places dominating in terms of their connections to other places.

- P2: The corporate network of the most influential MNCs is expected to cover the world evenly and without too much spatial differentiation, especially in developed and emerging markets.

3 Methodology

With their hierarchical structure of headquarters and numerous subsidiaries, a network perspective seems appropriate to visualise and analyse the corporate structure of MNCs. Such analyses allow for two things: 1) The examination of capital, product and knowledge flows within MNCs (Morschett, Schramm-Klein, & Zentes, 2015), and for 2) the investigation of patterns of global reach and local embeddedness with important implications for 1) (Verbeek, 2019). Since corporate networks can be conceptualised in terms of nodes representing headquarters and subsidiaries and links indicating the relationships between these entities, SNA is identified as a suitable tool for this thesis. To provide a basic understanding of the method, its origin and main features are presented below. Further concepts that are of interest for describing and analysing the corporate structure of the water sector will be introduced thereafter. These relate to the visualisation and analysis of individual and joint corporate networks, the identification of spatial interlocks between MNCs and the comparison of the joint corporate network with the spatial distribution of important actors of the "generalised others", more precisely with the most influential consulting and engineering firms in the water sector.

3.1 Origin and Basics

According to Wasserman and Faust (1994) "[a] social network consists of a finite set or sets of actors and the relation or relations defined on them", and SNA provides a method for defining these social concepts. The main object of SNA lies in the representation and measurement of network structures in order to explain their emergence as well as their impacts (Yang, Keller, & Zheng, 2016). While the development of SNA can be attributed to psychiatrist Jacob Moreno, who developed the technique of sociometry to measure social relationships, SNA is now employed in various disciplines such as sociology, psychology, political science as well as economics (Yang, Keller, & Zheng, 2016). As Ter Wal and Boschma (2009) point out, SNA has also received increased attention in economic geography, where the empirical analysis of inter-organisational interactions and knowledge flows across regions is central. Under the premise that transregional networks are socially constructed concepts through which knowledge diffuses, SNA has been used in regional network analysis to explain, among other things, cognitive lock-ins resulting from certain network structures (Ter Wal & Boschma, 2009).

The following theoretical elaborations are exclusively based on Wasserman and Faust (1994) and Yang et al. (2016), unless otherwise indicated. In general, a social network consists of a set of nodes N with f actors, $N = \{n_1, n_2, ...n_f\}$, which are connected through a set of linkages $X = \{x_{ij}\}$ (also named edges, links and arcs) representing relationships. Depending on the aggregate level of the nodes, networks are defined as one-mode or two-mode networks. In a one-mode network, actors are of the same type so that only a single set of actors is analysed. In contrast, in a two-mode network two different sets of actors exist and the actors of the first set are linked to the actors of the second network through a certain type of relationship. Popular examples of two-mode networks include affiliation networks, where one set of actors is analysed in terms of their affiliation to a second set representing events or other activities. In addition, SNA distinguishes two types of relationships. An undirected network is present when no distinction is made between sending and receiving nodes. A directed network, on the other hand, is present when certain nodes act as the source for outgoing links while others act as the target for incoming links. With these conceptual basics in mind, a social network can now be described by two sets of data, one focusing on the nodes and the other on the relationships between the nodes. Two of the most common ways of representing the relationship between the nodes are an edge list and an adjacency matrix. In an edge list, a link between two nodes is listed as one observation; in a two-mode network, a distinction is made between a sending column and a target column. An adjacency matrix **X** indicates, in contrast, in its elements x whether nodes are adjacent or not. For this purpose, the values 0 and 1 are used in a binary network to indicate the presence or absence of edges. In addition to the binary network, there are also valued networks in which the relationship between the nodes can be weighted, i.e. the elements of the adjacency matrix can assume values other than 0 and 1. An one-mode binary network of the size $(f \times f)$ with $f = 6$ could then be represented in one of the following four ways, with equation 1 presenting the adjacency matrix in matrix connotation, with x taking values of 0 or 1, and Figure 4 visualizing the network:

Table 2 Adjacency matrix and edge list for an one-mode binary undirected network.

X

	n_1	n_2	n_3	n_4	n_5	n_6
n_1	-	0	0	0	1	1
n_2	0	-	1	0	0	0
n_3	0	1	-	0	0	0
n_4	0	0	0	-	1	1
n_5	1	0	0	1	-	1
n_6	1	0	0	1	1	-

n_1	n_5
n_1	n_6
n_3	n_2
n_4	n_5
n_4	n_6
n_5	n_6

$$X = \begin{bmatrix} x_{11} & \cdots & x_{16} \\ \vdots & \ddots & \vdots \\ x_{61} & \cdots & x_{66} \end{bmatrix} \tag{1}$$

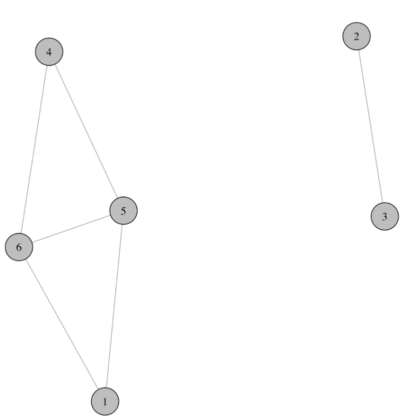


Figure 4 One-mode binary undirected network

3.2 Further Concepts

As a first step, this thesis aims to map the corporate networks of the individual MNCs as well as for all MNCs combined. To this end, nodes $N = \{n_1, n_2, ...n_f\}$ are defined as the location of a headquarter or subsidiary, while links $X = \{x_{ij}\}$ denote a relationship between a headquarter and subsidiary location. Since, according to Yang and Dong (2016), headquarter and subsidiary data is well captured in a directed network, the corporate networks will be represented as city-city one mode networks with only headquarter locations being able to establish links to subsidiary locations. As a headquarter might decide to establish several subsidiaries in one city, the network is weighted, where x indicates the number of subsidiaries established.

Just as in Verbeek (2019), the importance of a city will be illustrated using the centrality measure *degree*. The *degree* $d(n_i)$ of a node n_i describes how many links are incident with it, regardless of these links being outgoing of ingoing, and can be derived as follows:

$$d(n_i) = \sum_{j=1}^{f} x_{ij} \tag{2}$$

In the exemplary network, nodes 5 and 6 exhibit the highest *degree* of 3, since both nodes are adjacent to 3 other nodes. Likewise, nodes 2 and 3, which are only adjacent to each other, have a low *degree* of 1. In the spatial networks, the *degree* will be reflected by the node size, which indicate places of major activity in the water sector. While cities with a high degree are expected to occupy a central position in the network, cities with a low degree are assumed to hold a peripheral position.

Further measures can be calculated for the complete corporate network to identify central and peripheral cities. Following Yang and Dong (2016), the directed nature of the network allows for the calculation of *indegrees* and *outdegrees* for the nodes. While a *indegree* $d_I(n_j)$ refers to the number of links to a node, the *outdegree* $d_O(n_i)$ refers to the number of links from a node. Following the equation 3 the *indegree* can be calculated for the subsidiaries, while with equation 4 the *outdegree* can be derived for the headquarter locations.

$$d_I(n_j) = \sum_{i=1}^{f} x_{ji} \tag{3}$$

$$d_O(n_i) = \sum_{j=1}^{f} x_{ij} \tag{4}$$

According to Wall et al. (2011) a high *outdegree* is an indicator of a cities power over others, while a high *indegree* suggests a certain "prestige" of a city. However, given the research objective of this thesis and the fact that a high *indegree* indicates a large involvement of MNCs in the water infrastructure provision of a city, the measure of "prestige" can also be reinterpreted as a measure of "dependence" on regime solutions.

In a second step, the complete corporate network is analysed with regard to spatial interlocks between the locations of different MNCs. This is done because the one-mode city network may be skewed in the sense that a MNC decides to establish multiple subsidiaries in the same city. These cities can therefore score highly on centrality measures, even though they are not particularly powerful in terms of hosting different MNCs.[10] To construct an undirected two-mode company-city network, a matrix $\mathbf{Y}$ of the size $(n \times m)$ is created. While the rows label the nodes describing the MNCs c, the columns label the nodes l which refer to the different cities where at least one company is present. MNCs are therefore considered as the first set of actors that have a relationship with the second set of cities by having established a subsidiary. Since only the presence of an MNC in a city is of interest, the network will take a binary form. In the following the adjacency matrix $\mathbf{Y}$ for the company-city network is depicted in Table 3 as well as in equation 5:

[10] An analysis of spatial interlocks has been also conducted by Verbeek and Mah (2020) in order to identify patterns of integration and isolation within the petro-chemical industry.

Table 3 Adjacency matrix for the two-mode binary company-city network.

Y

	l_1	$\dots$	l_m
c_1	e_{11}	$\dots$	e_{1m}
$\vdots$	$\vdots$	$\ddots$	$\vdots$
c_n	e_{n1}	$\dots$	e_{nm}

$$Y = \begin{bmatrix} e_{11} & \dots & e_{1m} \\ \vdots & \ddots & \vdots \\ e_{n1} & \dots & e_{nm} \end{bmatrix} \tag{5}$$

Visualising the two-mode company network as a one-mode network then makes it possible to identify both the number of absolute shared locations between the MNCs and the cities where most companies are present.

Since a static network analysis will be conducted, the analysis can be seen as a snapshot in time (Verbeek & Mah, 2020). While to some extent, the analysis may reflect past events, present interdependencies and possible future paths (Verbeek & Mah, 2020), dynamic conclusions are beyond the scope of the analysis. To compensate for this to some extent, in a third step, the locations of the most influential water consulting and engineering firms will be mapped to show where regime rationalities will potentially spread in the future. In addition, the mapping will also give an indication of where regime rationalities may already be present in the context of public sector involvement. Finally, the separation of the mapping of water MNCs and consulting and engineering firms allows to solve the problem that, as will be explained in section 4.2, the same sampling criteria could not be applied to both categories of firms. Overall, it is expected that a joint representation of the entire network of companies and the locations of consulting and engineering firms will lead to an accurate representation of the global regime in the water sector in terms of private actors.

As a statistical tool, R will be used for both the mapping as well as the analysis of the corporate network. Since it has become the de-facto standard of statistical research, various R extension packages such as *igraph* exist for generating, manipulating, analysing and visualising network data (Kolaczyk & Csárdi, 2014).

4 Data

The selection of the companies whose corporate network is to be analysed is based on purposive sampling, a strategy that belongs to the non-probability sampling methods. Purposive sampling refers to the subjective inclusion of elements in the sample based on their characteristics (Etikan, Musa, & Alkassim, 2016). In this sense, the MNCs were selected on the basis that they will provide unique and rich information about the global regime of the water sector. While purposive sampling does not allow for statistical generalisation beyond the present study (Etikan, Musa, & Alkassim, 2016), the sampling approach does allow for analytical generalisation and thus the application of the conceptual, methodological and analytical approach beyond this thesis.

4.1 Sampling of the Private Water MNCs Data Set

To identify the target population of the most influential MNCs in the global water sector, the two approaches of positional and reputational boundary definition described by Yang et al. (2016) were combined. To this end, MNCs were identified based on their position in the "The world's top 50 private water operators" list published by Global Water Intelligence (2019), which ranks 50 private water utilities by the number of people they serve. The list is well representative of the private global water sector, as a careful triangulation of various rankings in journals or databases such as LexisNexis (2021), Orbis by Bureau van Dijk (2021), Statista (2020) and articles by the Public Services International Research Unit of the University Greenwhich confirmed. Triangulation refers to the use of multiple data sources and was conducted to develop a comprehensive understanding of the global water sector and increase the validity of the final sample (Carter, Bryant-Lukosius, & DiCenso, 2014; Wilson, 2014). However, triangulation of data may be criticised for treating data collected by different methods as equivalent and therefore needs to be used with caution (Wilson, 2014).

Subsequently, the companies included in the GWI list were sorted according to the criteria of whether they are a MNC and the data availability is sufficient for the analysis. This means that companies that do not have entities in two or more countries were excluded (Morschett, Schramm-Klein, & Zentes, 2015). In order to increase the validity of the resulting sample of 20 companies, it was assessed by researchers at the Swiss Federal Institute of Aquatic Science and Technology (Eawag) in terms of its representativeness of the global water sector. Of the remaining 18 companies, ten were included in the final sample. This choice is justified by the existence of a clear threshold within the list of 18 companies in terms of the number of subsidiaries and annual turnover. As six of these ten companies are headquartered in Europe and four in Asia, two major American water companies were also included in the sample for the purpose of global representativeness. Again, the selection was based on their position in rankings and their reputation in professional circles. Although the selection of data was carefully carried out using the positional and reputational approach, there is still a risk that companies were overlooked. When deriving implications for the analysis of corporate network structures, it should therefore be considered that a distortion of the network structure by neglecting other important actors cannot be ruled out (Yang, Keller, & Zheng, 2016). An overview of the MNCs which were finally included in the sample and are expected to be part of the core of the global water regime is provided in Table 4.

Table 4 Overview about the water MNCs in the sample.

	Headquarter	Founded (in its current form)	Employees (2020)	Operating revenue (Turnover) in thd US$ (2020)	Area of activity
Suez	Paris, France	2000	89,352 (2019)	21,676,464	Utilities
Veolia Environnement	Paris, France	1995	178,894	31,916,730	Utilities
Beijing Enterprise Water	Beijing, China (registered in Hamilton)	1993	18,424	3,770,645	Communications
VA Tech Wabag	Chennai, India	1995	1,009 (2019)	339,208	Waste Management and Treatment
Acciona Aqua	Alcobendas, Spain	1975	2,894	720,398	Utilities
FCC Aqualia	Madrid, Spain	1980	8,662	1,376,045	Utilities
Manila Water	Quezon City, Asia	1997	2,172	647,710	Utilities
China Everbright Water	Hong Kong, China (registered in Hamilton)	2003	2,231	743,333	Utilities
Remondis Aqua	Lünen, Germany	1968	95	61,955 (2019)	Utilities
Eranove	Puteaux, France	2003	8,575 (2019)	759,308 (2019)	Business Services
Xylem	Rye Brook, US	2011	16,700	4,876,000	Industrial, Electric & Electronic machinery
Aquatech	Canonsburg, US	1981	125	62,600	Utilities
All			329,133	66,305,483	

Note: Data extracted from Orbis (Bureau van Dijk, 2021).

The data for the headquarter and subsidiaries of the respective companies were derived in March and April 2021 from the Orbis database, which describes itself as "the world's most powerful comparable data source on private companies, with information on more than 375 million companies around the world" (Bureau van Dijk, 2021). In the process, all currently active subsidiaries that are linked to their ultimate owner via at least 50.01 percent of minimum control were filtered out via ten levels of ownership.[11] The decision to limit the sample of subsidiaries to majority-owned subsidiaries is based on the idea that regime rationales spread most rapidly when the parent company has decision-making power over the subsidiary's activities. To ensure the informative value of the sample, subsidiaries with data older than 2019 as well as those without location data and unclear ownership relations were excluded. In a next step, it was filtered for water-related subsidiaries. As some of the companies listed above are active in other areas apart from their main activity in the water sector, only subsidiaries that correspond to the thesis' definition of the water sector either in their name or in their NACE Rev. 2 industry code were included in the sample.[12] This approach was considered the most appropriate to ensure that subsidiaries are truly

[11] The ownership level refers to the fact that a parent company can establish a subsidiary, which in turn can establish a subsidiary and so on. These types of relationships are considered over 10 levels.

[12] NACE Rev.2 is the statistical classification of economic activities applied in the European Union. The industry codes which were identified as relating to the definition of the water sector are division 36 ("collection, treatment and distribution of water for domestic and industrial needs"), division 37 ("the operation of sewer systems or sewage treatment facilities that collect, treat and dispose sewage") and the class 41.91 referring to the construction of water projects (eurostat, 2002, pp. 204–205).

active in the water sector and thus part of the global water regime. Nevertheless, a screening of all subsidiaries for main activities and data validity would result in a more comprehensive and complete representation of the global water sector.

Before the remaining subsidiaries' city locations were geocoded in order to prepare the data set for the spatial mapping, it was ensured that no subsidiary was included twice in the sample. Since self-loops make a social network analysis very difficult and cannot be captured in the spatial mapping of headquarter and subsidiaries relationships, the subsidiaries located in the same city as the headquarter were excluded in a final step. In general, the data derived from the Orbis database were considered to be correct, although researchers such as Verbeek and Mah (2020) mention that the data quality at Orbis can vary, especially for non-European and non-American countries.[13] As an attempt to counteract this flaw, only subsidiaries with recent data were included in the analysis. However, future studies should, if possible, cross-check the data for all subsidiaries against a second database. Table 5 gives an overview of the final sample of headquarter and subsidiary locations for the spatial mapping and the SNA.

Table 5 Overview about the headquarters and subsidiaries of the water companies in the sample.

	Number of water related subsidiaries	**Unique city locations**	**Number of connections excluding subsidiaries in the same city as the HQ**
Suez	163	91	163
Veolia Environnement	281	171	274
Beijing Enterprise Water	152	89	145
VA Tech Wabag	5	6	5
Acciona Aqua	29	13	17
FCC Aqualia	73	35	48
Manila Water	7	3	7
China Everbright Water	15	12	15
Remondis Aqua	24	16	16
Eranove	2	3	2
Xylem	51	40	51
Aquatech	6	6	6
All	808	434	749

Note: Data extracted from Orbis (Bureau van Dijk, 2021).

4.1.1 Overview of the Private Water MNCs Data Set

The final data set, which aims to capture the headquarters and subsidiaries of the most influential private MNCs with main activity in the water sector, includes six companies based in Europe, four based in Asia and two based in North America. One-quarter of the companies are headquartered in France, with the two largest companies in terms of operating turnover and employees based in Paris. This includes the global holding company Suez, which is active in the field of environmental services and specialises in the water sector in drinking water supply and wastewater treatment. The second company is Veolia Environnement, a global group for optimised resource management, which, like Suez, focuses on drinking water, wastewater and

[13] An exception was made for the head office locations of Beijing Enterprise Water and China Everbright Water. As the head offices of the companies are registered in Bermuda for financial reasons, it cannot be assumed that majority control is exercised from there. For this reason, Hong Kong was chosen as the headquarters for China Everbright Water, as the parent company China Everbright Environment is registered there. For Beijing Enterprise Water, Beijing is assumed to be the actual headquarters, as this is also stated on the company's website.

sewage treatment plants and supply systems in its water segment. Suez and Veolia alone account for around 81.5 percent of the employees in the sample. Similarly, they together generate about 80.8 percent of the annual turnover among the companies included in the sample. Therefore, a clear threshold to the third-ranked MNC by the number of people served, Beijing Enterprise Water, becomes apparent. As shown in Table A1 in the appendix, which provides contextual information on the companies included in the sample, all companies, including the three already mentioned, operate entirely within the "market logic" of the water sector, making them truly representative of traditional solutions and approaches.

According to the sampling criterion that the subsidiary refers to the definition of the water sector in its name or industry code, the 12 companies are active in 434 different cities with their headquarters and 808 subsidiaries. If the subsidiaries in the same cities as the headquarters are disregarded, 749 headquarter-subsidiary links remain. Again, Table 5 indicates a threshold in the sense that Veolia and Suez account for the majority of subsidiaries in the sample, namely 58.3 percent. However, the threshold emerges with the fourth-placed Indian company VA Tech Wabag, as Beijing Enterprise Water has a similar presence to Veolia and Suez in terms of water-related subsidiaries.

4.2 Sampling of the Consultancies and Engineering Companies Data Set

The identification of consulting and engineering firms that are not exclusively active in the water sector, but are nevertheless key players, was carried out in a similar way to the major water MNCs above. Again, several sources were triangulated in order to identify the most influential players. To this end, memberships in associations as in the Water Industry Forum (2021), reports about the water sector (New Civil Engineer, 2009; WaterWorld, 2001) as well as rankings such as the ENR 2019 Top 200 Environmental Firms (2020) were cross-checked to find actors who appear on all lists. Five companies were present on all lists and also passed the reputational check by researchers from Eawag. As with the water MNCs these companies are presented in the following Table 6, in which they are ranked according to their percentage of 2018 gross revenue from environmental services.

Table 6 Overview about the consultancies and engineering firms in the sample.

	Headquarter	**Founded (in its current form)**	**Employees**	**Operating revenue (Turnover) in US$ (2020)**	**Area of Activity**
AECOM	Los Angeles, US	1980	54,000	13,239,976	Business Services
Jacobs	Dallas, US	1987	55,000	13,566,975	Construction
Black & Veatch	Leawood, US	1915	9,600 (2019)	2,307,000	Business Services
WSP	Montréal, Canada	2006	50,000 (2019)	6,848,087	Business Services
Mott MacDonald	Surrey, UK	1973	15,297 (2019)	2,340,880 (2019)	Business Services
All			183,897	38,302,918	

Note: Data extracted from Orbis (Bureau van Dijk, 2021).

Also here, subsidiaries over ten levels of majority ownership were included when the data was not older than 2019 and the location was given in the Orbis database. Since the consulting and engineering firms included in the above-mentioned reports and lists are important actors in the water sector but are not mainly active there, it was not possible to apply the same sampling criteria as for the water companies. Neither their names nor their industry codes referred to the water sector in the majority of cases. This was one reason to separate the spatial mapping and analysis of water MNCs and consulting and engineering firms. As they are nevertheless part of the global regime, the subsidiary locations of the five companies were also geocoded so that their location could be mapped for visual analysis. Again, subsidiaries that were included in the sample for a second time were excluded. Table 7 displays the number of subsidiaries for each company as well as the unique city locations identified for each company and for all companies together.

Table 7 Overview about the consultancies and engineering headquarters and subsidiaries in the sample.

	Nr. of subsidiaries included in the sample	**Unique city nodes (HQ + subsidiaries)**
AECOM	314	154
Jacobs	339	172
Black & Veatch	43	29
WSP	121	66
Mott MacDonald	68	23
All	885	353

Note: Data extracted from Orbis (Bureau van Dijk, 2021).

4.2.1 Overview of the Consultancies and Engineering Companies Data Set

A look at Table 6 and Table 7 may explain the underrepresentation of the Anglo-American region in the data set of water MNCs. All five companies in the data set of consultancies and engineering companies are from this region, three from the US and one each from Canada and the UK. This suggests that actors from this area are very active in the global water regime, albeit not in the utilities but the business services and construction sectors. While all the companies in the sample offer a wide range of engineering, construction and consultancy services, they are involved in the water sector to varying degrees. Activities range from technical consultancy in water supply, wastewater recycling and water management in the case of Mott MacDonald, to involvement in architectural design and construction services in the water sector by AECOM. Overall, similar to the water MNCs, additional contextual information in Table A2 in the appendix indicates a strong involvement of all consulting and engineering firms in the application and diffusion of traditional solutions in terms of the "market" and "hydraulic logic" in the water sector. Also in this data set, the two largest companies, AECOM and Jacobs from the US, stand out in terms of employees and operating turnover. However, a clear threshold, as in the data set of the water MNCs, is not evident to the same extent. Together, the five companies are present in 353 different locations with their headquarters and their 885 subsidiaries.

5 Results

In order to characterize the global socio-technical regime of the water sector, this section presents in three parts: 1) The results of the spatial mapping, regional analysis and SNA of the water companies' corporate network, 2) the results of the investigation of spatial interlocks between the water MNCs, and 3) a visualisation of the locations of the consultancy and engineering companies active in the water sector.

5.1 Spatial Mapping and Regional Analysis

Mapping the corporate networks of the largest water MCNs makes it possible to reveal patterns of regional concentration and dispersion between different networks and the hierarchy within the overall corporate network. The following analysis is based on the visualisation of the network and identified regional patterns. To illustrate the possible channels of regime rationalities, the relationships between headquarters and subsidiaries were defined in such a way that subsidiaries at all levels were established directly from headquarters. Note that the node size of the different locations is proportional to the degree of the cities, i.e. the number of connections this city maintains, as explained in section 3.2. To further illustrate the importance of individual locations for the global water regime, SNA measures are subsequently applied.

5.1.1 Spatial Mapping of the Corporate Networks

As can be seen in Figure 5 and Figure 6, the corporate networks of Suez and Veolia span the globe, with both companies being present on all continents. While both companies have their main activities in Europe, their corporate networks extend to regions peripheral to the European contexts such as Australia and New Zealand, Latin America or Sub-Saharan Africa. While Suez has established its largest share of subsidiaries (64) in Southern Europe and Veolia's core activity is in Western Europe (120 subsidiaries), the second area of interest for both companies is North America with 47 and 45 subsidiaries respectively. The outstanding position of the two companies in the hierarchy of private water companies compared to the other companies is not only reflected in the number of subsidiaries, but also in the regional orientation across the entire world and thus in the high regional dispersion of entrepreneurial activities.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure 5 Corporate network of Suez.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

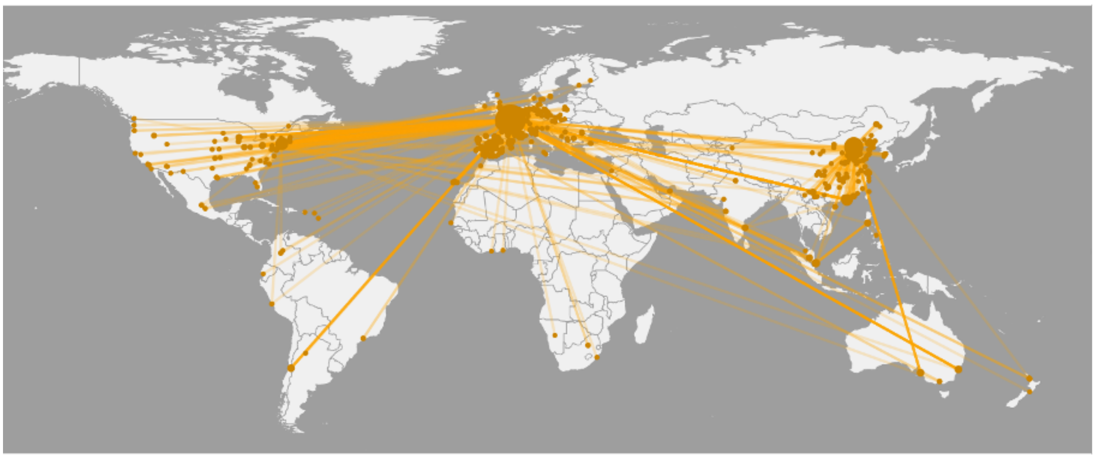
Figure 6 Corporate network of Veolia.

The other corporate networks, which can be found in the appendix, seem to be more focused on specific areas. A good example is the Chinese company Beijing Enterprise Water (Figure A1), which has a similar number of subsidiaries as Suez, but has about 89 percent of its activities in Eastern Asia, besides a few presences in New Zealand, Australia and Portugal. The same applies to the networks of Acciona Aqua (Figure A3) and FCC Aqualia (Figure A4), which are mainly active in the region of their headquarters, but have also established some subsidiaries in distant locations. Acciona Aqua's network is particularly noteworthy, with a few subsidiaries spread across four additional continents. The other company networks are less remarkable in the sense that the regional concentration can be considered quite high with some exceptions such as the European representations of VA Tech Wabag (Figure A2) or the Indian branch of Remondis in Pune (Figure A7). Eranove's corporate network (Figure A8) is interesting in that the company is headquartered in Puteaux, France, but is only active in Sub-Saharan Africa with two subsidiaries in the former French colonies Senegal and Côte d'Ivoire. This brings valuable implications for sustainability transitions, as regime rationalities seem to be formulated in a different regional context than the one in which they apply in Eranove's case.

The corporate networks of the North American companies, on the other hand, show a stronger regional dispersion. Xylem (Figure A9) is active on almost all continents, although with a focus on North America and Northern Europe with 18 and 11 subsidiaries respectively. Aquatech (Figure A10), with its relatively small number of subsidiaries, also achieves a high degree of regional dispersion with presences in Northern America, Eastern Asia, Southern Asia and Western Asia.

If all corporate networks are now mapped together in Figure 7, the extreme spatial extent of the global regime across all continents becomes evident, especially covering developed and emerging economies. To a certain extent, the corporate network appears to reflect the history of European and especially French colonialism. History seems to predetermine where European headquarters establish their subsidiaries and thus continue to influence urban infrastructure development. Furthermore, as node size represents a city's connections, the importance of headquarter locations such as Paris, Madrid and Beijing becomes clear, with connections from these locations spanning the globe. Only certain regions, such as the African continent and some parts of Latin America and Asia, appear to be largely peripheral in this network. Interestingly, these include the BRICS countries, which are not yet as integrated into the regime, making Russia and Brazil in particular, and to a lesser extent India and South Africa, weaker spots in the global regime.

In general, the picture derived from spatial mapping largely supports propositions one and two regarding a global corporate network that is dominated by specific actors, namely Veolia and Suez, and cities such as Paris, Madrid and Beijing. Through the spread of the network to all world regions, regime rationalities seem to have been institutionalised in different contexts, strengthening the global regime and thus weakening its capacity for transformation. Also, the hierarchy within the network through the dominance of European actors in terms of regional spread indicates the existence of a strong regime within the global sector. These actors seem to be capable of maintaining the current course of the global regime through their structural power within the regime.



Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure 7 Overall corporate network.

5.1.2 Regional Analysis

In addition to the spatial mapping, a regional analysis was conducted to get an impression of the spatial strategies of the MNCs depending on their origin. For this purpose, the parent companies were divided into North American, European and Asian companies and the subsidiaries were assigned to one of 15 sub-regions, using the regional classification of the United Nations Statistics Division (2021). The results of the regional analysis are presented in Table 8.

Table 8 Regional analysis of subsidiary locations from Northern American, European and Asian companies.

HQ	**Northern America**		**Europe**		**Asia**	
Subsidiaries	N	%	N	%	N	%
Northern Africa			1	0.02		
Sub-Saharan Africa			7	1.4		
Latin America + Carribeans	3	5.3	20	3.9		
Northern America	20	35.1	94	18.1		
Central Asia						
Eastern Asia	2	3.5	37	7.1	145	84.3
South-Eastern Asia	2	3.5	10	1.9	11	6.4
South Asia	3	5.3	5	0.1		
Western Asia	2	3.5	3	0.06	1	0.06
Eastern Europe			28	5.4	1	0.06
Northern Europe	11	19.3	18	3.5		
Southern Europe	4	7.0	134	25.8	3	1.7
Western Europe	8	14.0	145	25.2	1	0.06
AU + NZ	2	3.5	18	3.5	10	5.8
Oceania						

Note: Author's own calculation based on data from Orbis (Bureau van Dijk, 2021).

The Northern American companies, which account for 7.5 percent of the subsidiaries in the sample, are active in ten out of 15 regions, however, mainly in Northern America (35.1 percent) and in Northern (19.3 percent) as well as Western Europe (14.0 percent). Interestingly, they do not have any subsidiaries in developing regions. The European companies with 68.8 percent of the subsidiaries in the sample are active in almost all regions except Central Asia and Oceania. Compared to their Northern American counterparts, they show a slightly higher regional dispersion with their main activity in Southern (25.8 percent) and Western Europe (25.2 percent), followed by Northern America (18.1 percent) and Eastern Asia (7.1 percent) and Eastern Europe (5.4 percent). In line with proposition two, entrepreneurial activity dominates in developed and emerging economies, while developing regions are neglected. The Asian firms, with 22.8 percent of the subsidiaries in the sample, are almost only active in Eastern Asia (84.3 percent), succeeded by South-Eastern Asia (6.4 percent) and Australia and New Zealand (5.8 percent). The focus of their activities is thus on emerging economies followed by developed economies. Overall, the regional dispersion seems to be led by European companies followed by Northern American companies, while Asian companies mainly focus on their surrounding market, with few exceptions mainly involving Australia and New Zealand.

Similar to the previous examination of the corporate network structure, the regional analysis reveals a hierarchical network structure in which European and, to some extent, North American firms dominate the regime and thus the diffusion of rationalities through their widely dispersed activities. Rationalities formulated in the context of headquarters locations in France, Spain, Germany and the US manifest in more regional contexts than in the case of Asian companies, reinforcing the dominance and power of these firms in the regime. For the intended sustainability transitions, it is therefore expected that these companies are able to resist change across multiple contexts and thus largely prevent the opportunity for transformation. However, regions in Africa, Central Asia and Latin America are barely covered by the strategies of the MNCs, making them potential sites for change as regime rationalities are not yet institutionalised and leave room for experimentation and alternatives.

5.1.3 Application of SNA Measures

This section aims to provide more clarity on the hierarchy in the global water regime by providing insights into the dominance of certain locations over others.[14] To this end, Table 9 presents centrality measures that provide information on cities that stand out from others. Unsurprisingly, cities with a high *outdegree* represent headquarter locations. Therefore, Paris, headquarter of Suez and Veolia, scores highest with an *outdegree* of 437, followed by Beijing, headquarter of Beijing Enterprise Water, with an *outdegree* of 145, and Rye-Brook, headquarter of Xylem with an *outdegree* of 51. It is likely that these few locations exercise the greatest power within the global regime and determine the trajectory of the regime. This makes the respective companies, including their locations and strategies, a factor that absolutely must be taken into account when it comes to taking action in the context of sustainability transitions. In contrast, the *indegree* gives the most important subsidiary locations in the sample. Here, Hong-Kong leads with 23, succeeded by Barcelona with 17 and Singapore and London with an *indegree* of 13 each. Being in the position of recipients, these cities are highly dependent on the MNCs for the design and management of their urban water infrastructure, which arguably does not make them conducive to change. Of particular interest are the cities with a high *indegree* but *outdegree*

[14] An illustration of the one-mode city-city network can be found in Figure A11 in the appendix.

of zero, i.e. the cities in non-bold, as they represent the passive recipients of regime solutions without the headquarters being located in them. Cities with an *indegree* of above 5 are exclusively located in eight countries, with Spain, France, China and the United States also representing headquarters locations, and the United Kingdom, Malaysia, Australia and Chile only being recipient countries of the solutions offered by the companies in the sample. Again, the developing countries and the BRICS states do not appear as passive recipients and could therefore represent places for the emergence and institutionalisation of alternative rationalities. Lastly, adding up the *outdegree* and *indegree*, the *degree* results. The first places in the ranking of *degree centrality* are occupied by the headquarter locations due to their high *outdegree*. However, Madrid scores higher because subsidiaries are also located in the city. In addition, cities such as Barcelona, Singapore and London are in the top ten and thus constitute central locations within the global regime.

Table 9 Centrality measures for the overall corporate network. Cities in bold letters represent headquarter locations.

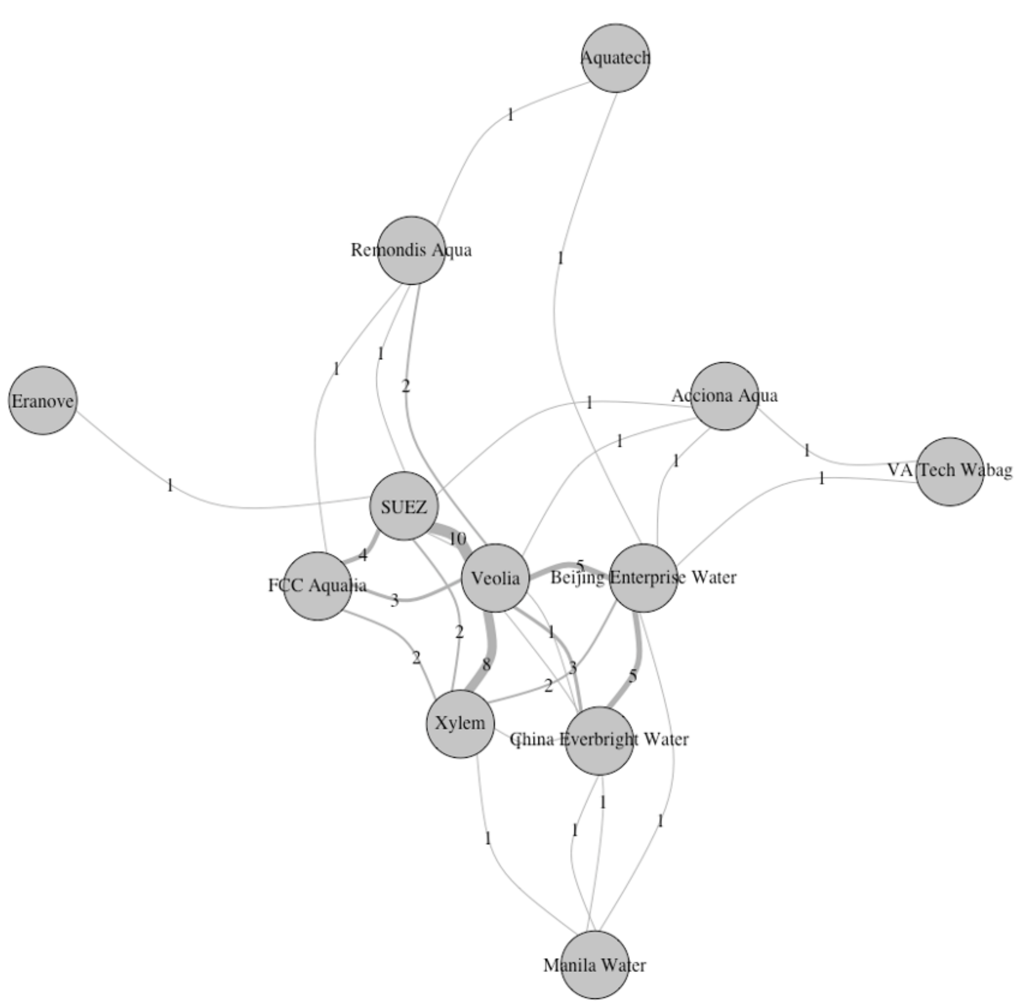
	Degree (Out- + Indegree)	**Outdegree**	**Indegree**
Paris	437	437	
Beijing	146	145	1
Madrid	58	48	10
Rye-Brook	51	51	
Hong-Kong	38	15	23
Alcobendas	17	17	
Barcelona	17		17
Lünen	16	16	
Singapore	13		13
London	13		13
Nanterre	11		11
Adelaide	9		9
Pyrmont	9		9
Santiago	9		9
Milano	8		8
St-Maurice	8		8
Marseille	8		8
Kunming	7		7
Kuala-Lumpur	7		7
Paramus	7		7
Chennai	6	5	1
Cannonburg	6	6	
Jieyang	6		6
Milwaukee	6		6
Nottingham	6		6
Bilbao	5		5
Qiquihar	5		5
Indianapolis	5		5
Nantes	5		5
La-Garde	5		5
...	...	...	...
Puteaux	3	2	1

Note: Author's own calculation based on data from Orbis (Bureau van Dijk, 2021). Note that the centrality measures are provided for headquarter locations and subsidiary locations with an *indegree* of five and above.

Considering all measures together, it becomes evident that in accordance with proposition one certain cities dominate others. This is not only the case because they represent headquarter locations, but also because they are welcome locations for the establishment of subsidiaries. However, these cities are not only located in one regional context, but are spread across three continents, which supports proposition two indicating a strong global regime. Overall, the first part of the analysis paints a picture of a strong global regime within the global water sector, dominated by European and particularly French actors, whose main activities are distributed among industrialised countries and, to a lesser extent, emerging economies. The dynamics within the regime are therefore highly influenced by these actors, who are assumed to have an interest in maintaining the prevailing rationalities, so that the transformation capacity of the global regime is weakened.

5.2 Spatial Interlocks

As mentioned earlier, the analysis of a one-mode city-city network can be misleading in that companies might decide to establish multiple subsidiaries in one city. This might overemphasise the importance of some cities while saying little about the spread of regime rationales in the global socio-technical regime. In order to show where firms are actually interconnected in their locations, a two-mode network was constructed to identify spatial interlocks. An analysis of this network is intended to reveal the companies which form the core of the global regime and the cities in which most of them are present. To this end, Figure 8 depicts the absolute number of shared locations.



Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure 8 Two-mode network depicting the absolute number of shared locations of the water MNCs.

In absolute terms, Veolia and Suez share the most locations, namely 10. Furthermore, Veolia shares eight and five locations with Xylem and Beijing Enterprise Water respectively. The middle of the network can be interpreted as the core of the corporate network of the water MNCs, as six companies stand out with their activities in the same cities. In accordance with proposition two, the core of FCC Aqualia, Suez, Veolia, Xylem, Beijing Enterprise Water and China Everbright Water spans all of the three regions highlighted in section 5.1.2. Once again, Veolia's strong position within the global regime is underlined as it overlaps with nine out of eleven companies in its location. In general, private actors in the global water sector share several locations concentrated in the same regions, indicating the existence of a strong regime in these areas. It is also noteworthy that not a single company is isolated in its location, indicating a "compactness" of the network that allows regime rationalities to spread easily and quickly within the regime.

Overall, the depiction of spatial interlocks provides valuable insights for sustainability transitions, as it underpins the findings of section 5.1.3. As regime rationalities are generally expected to be the strongest where most companies are present, the question of where exactly the companies meet arises. An answer to this question is presented in Table 10. Previously highlighted cities such as Singapore, Madrid, Barcelona, Hong Kong, Kuala-Lumpur and Nanterre appear here alongside Dalian and Zaragoza which have not played a role so far in the analysis of the corporate network.[15] As these cities host several MNCs, they occupy a central position in the global regime. At the same time, however, they are dependent on traditional solutions, which limits their ability to develop their own alternative solutions.

Table 10 Cities where the most companies in the sample are present.

City	Nr. of companies present	Companies present
Singapore	5	Veolia, Beijing Enterprise Water, China Everbright Water, Manila Water, Xylem
Madrid	4	Suez, Veolia, FCC Aqualia, Xylem
Barcelona	3	Suez, FCC Aqualia, Remondis Aqua
Dalian	3	Veolia, Beijing Enterprise Water, China Everbright Water
Hong-Kong	3	Suez, Veolia, Beijing Enterprise Water
Kuala-Lumpur	3	Veolia, Beijing Enterprise Water, Xylem
Nanterre	3	Suez, Veolia, FCC Aqualia
Zaragoza	3	Suez, Veolia, FCC Aqualia

Note: Author's own calculation based on data from Orbis (Bureau van Dijk, 2021).

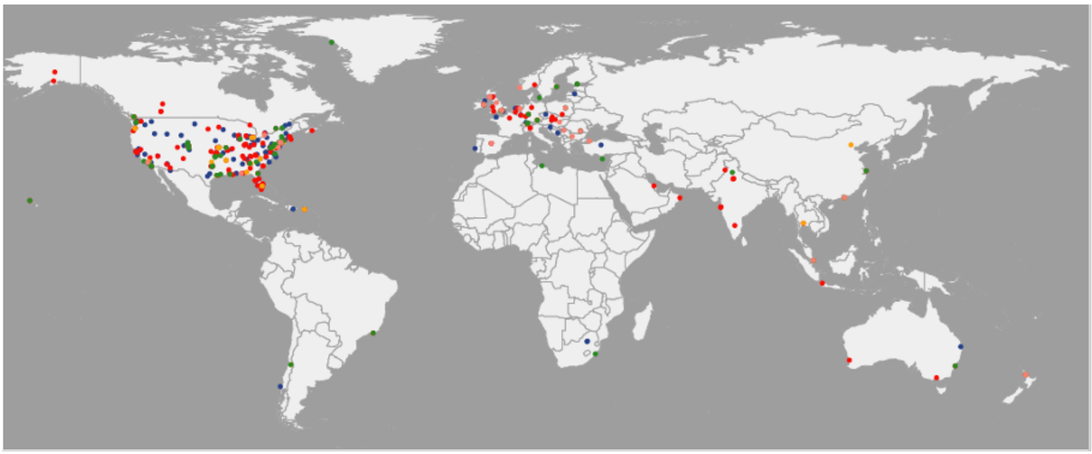
5.3 Spatial Mapping of the Consultancies and Engineering Companies

Finally, the spatial distribution of the activities of consulting and engineering firms that are not exclusively active in the water sector will be in focus. In the sense that these firms might provide services to private and public utilities, this is of interest in that their spatial distribution might reveal where regime rationalities are present in addition to the locations identified above. Furthermore, visualising the spatial distribution of their entrepreneurial activities gives an indication of where regime rationalities could potentially spread.

A first map Figure 9 displays the locations of AECOM (blue), Jacobs (red), Black & Veatch (orange), WSP (green), and Mott MacDonald (pink). Since only spatial dispersion is of interest here, no degree is applied. Interestingly, the same patterns emerge as for the water MNCs. The consulting and engineering firms have a global

[15] It is interesting to note that despite a high *indegree* and a high number of water MNCs residing in the city, Barcelona has developed its own on-site water reuse program, see for example Domènech, March and Saurí (2013). A study that would examine how Barcelona has managed to resist the pressure of the global regime would therefore be very promising in terms of insights into regime dynamics.

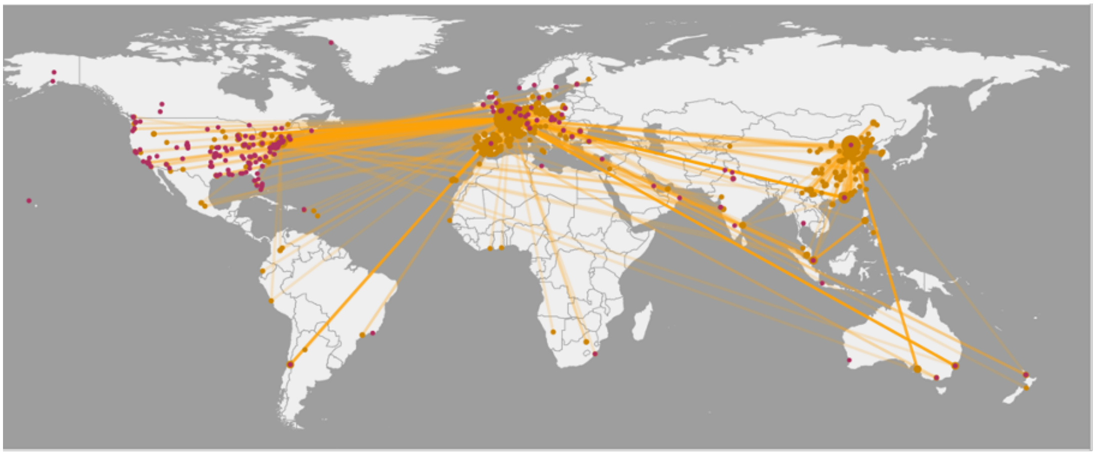
presence with their operations centered in North America and Europe, with additional subsidiaries in emerging markets such as the BRICS countries China, India, and South Africa. Consistent with the previous analyses, this confirms the strength of the regime in the North American and European contexts, while emerging markets are weaker points and developing countries are not part of the regime at all. There are only a few exceptions to this, such as a Black & Veatch subsidiary in Libya.



Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure 9 Headquarter and subsidiary locations of the engineering and consulting companies.

To determine if the water sector's corporate network actually overlaps with the locations of consulting and engineering firms, a second map Figure 10 was created that combines the two. A strong overlap and thus a similar geographical spread can be observed. The regime rationalities are therefore expected to be strongest where the companies of both samples are already present, thus in Northern America and Europe. As a consequence for sustainability transitions, there are certain regions where the most influential players in the water sector are not yet active. These are mostly in developing countries that are about to build water infrastructure in the next few years, making them interesting candidates for the emergence and establishment of sustainable alternatives. This finding is highly relevant and will receive more attention in the discussion section 6. Overall, Figure 10 again paints a picture of a global regime of water MNCs, consultancies, and engineering firms spanning the globe, with some regions more dominant than others. This confirms the characterisation of the global water sector regime as a strong regime, highlighting once again the difficulties in transforming the regime towards a more sustainable one due to the highly institutionalised structures across the world.



Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure 10 Spatial map of the corporate network of the water MNCs combined with the locations of the consultancies and engineering companies (red).

6 Discussion

The thesis aims to provide insights into the impact of corporate networks in global socio-technical regimes on sustainability transitions and to derive policy implications that result from network configurations. In particular, the focus is on the level and spatial context at which policy interventions are deemed relevant. In the following, these issues are discussed in detail based on the identified regime structures in the water sector and the possibility of sustainability transitions within and outside the current global regime. Although the implications presented here result from the analysis of the water sector, they can find application in other industries after their global regime has been characterized.

6.1 Regime Structures

In accordance with Fuenfschilling and Binz' (2018) definition of a global socio-technical regime, the analysis above has revealed an international actor-network that diffuses dominant institutional rationalities, mainly the "hydraulic logic" and the "market-based logic", across different contexts. Through the application of SNA, the global regime was further characterised as a compact, globe-spanning structure subject to a strong hierarchy with dominance of certain actors and regions. This is a structure that implies a direct transmission of regime rationalities through the GPN of the water sector, where Veolia and Suez have the most influence compared to the other companies in the sample. Since, according to Figure 10 much of the power in the global regime seems to emanate from Europe and Northern America, it is no wonder why Western infrastructure solutions prevail around the world. From these two regions, regime rationalities have been transferred to other developed and emerging economies through the establishment of subsidiaries. This in turn has contributed to the widespread adoption of large-scale network infrastructures, institutionalising this dominant rationality in a variety of contexts stabilising the global regime (Fuenfschilling & Binz, 2018). Here, i.e. in regions with a strong regime presence, radical innovations are rather unlikely and efforts to establish solutions in the direction of water-sensitive logic will have a hard time succeeding due to the great influence and power of the MNCs. In line with the statement of former Special Rapporteur Leó Heller (2020), distant regions that are nevertheless part of the water sector's GPN, such as Eastern European and Latin American countries, are expected to be under pressure from the global regime to adopt its favoured infrastructure solutions. It is further likely that as the level of development advances, the corporate network will begin to build its presence in the regions which are still peripheral to the regime. A first impression of this can be gained in countries such as Ghana, Senegal or Côte d'Ivoire, where Eranove and Veolia are already present. Thus, first and foremost, a national policy is recommended that shields the regions with weak or no regime presence identified in section 5 from the pressure of global regime actors to establish their traditional solutions.

Keeping an eye on Veolia and Suez will be particularly relevant in this regard. In addition to their already dominant position, the two companies are in the process of merging, which would result in 58.3 percent of the subsidiaries from the sample being controlled by the same headquarters in Paris (Bloomberg, 2021).[16] While the final agreement is expected by mid-2021, pending approval from competition authorities in various countries, the merger will "create a global giant in waste and water services under the Veolia umbrella" (Bloomberg, 2021). As this highlights Veolia's dominance,

[16] After months of resistance from Suez, an agreement was reached based on Veolia's offer to pay 20.50 euros a share for the remaining 70 percent it does not already own (Bloomberg, 2021).

it also reveals the limits of national policy initiatives in the water sector, apart from the influence that the French government might have. Besides the high degree of institutionalisation of the network in different contexts, the resistance strategies of influential incumbents such as Veolia are thus likely to hinder the success of policy efforts.[17]

Based on the previous elaborations, the global nature of the regime will make it necessary to shift the destabilisation pressure to the global level in order to allow other regime rationalities to emerge and promote the transition to sustainability. The framing activities of large donor agencies might play a crucial role in this sense. It is conceivable that initiatives as the "citywide inclusive sanitation" approach promoted by the World Bank which explicitly challenges the traditional paradigms of the provision of water sanitation, will have an impact on regime rationalities (World Bank, 2021). It is remarkable that an institution which has promoted the "market logic" for decades (Heller, 2020), calls now for rethinking the funding of sanitation infrastructure and challenging approaches that subsidise large-scale infrastructure but not on-site sanitation. The World Bank (2021) also notes that a shift in thinking is needed among governments, development agencies, consultancies and engineers to make sustainability initiatives a success. In doing so, it highlights, in line with the analysis of this thesis, that efforts should not only be directed at MNCs, but also at other elements of the global regime such as the identified engineering and consulting firms. As transnational linkages connect the different elements of the global regimes, a reorientation of their strategies as well will be inevitable for the success of any policy aiming at sustainability transitions.

6.2 Sustainability Transitions within the Global Regime

Contrary to the tendency in current research to focus on alternatives and actors outside the existing regime, sustainability transitions can also be accomplished within current socio-technical regimes (Turnheim & Sovacool, 2020). As Fuenfschilling and Binz (2018, p. 739) state suitably, "[a]n actor's capacity to exert institutional pressures as well as its position in the [...] international networks of sector's GPN will determine their power to change the trajectory of the regime". Clearly, all the companies analysed, but Veolia in particular, must be the subject of sustainability policies. While on the one hand, the MNCs are likely to continue to spread the "market logic" through their enormous geographical reach, on the other hand, they could represent a unique channel for the dissemination of more sustainable logics once they have been established in their corporate strategy. Here, different ways of influencing the incumbents' strategies are conceivable. These include making the local embeddedness of subsidiaries a prerequisite for their establishment, e.g. by largely mandating the use of local suppliers and employees. To a certain extent, this could reduce the influence of the headquarter and allow alternative solutions through the stimulation of a conflict between the local and the global level (Morschett, Schramm-Klein, & Zentes, 2015). Another option would be to increase the role of incumbents in sustainability experiments by creating conditions under which companies would benefit from participation (Sengers, Wieczorek, & Raven, 2019). Inspired by financial rewards, such as those offered by the World Bank's Citywide Inclusive Sanitation Initiative, established actors may recognise the value of transition initiatives and begin to in-

[17]In this context, the controversy surrounding UN Special Rapporteur Leo Heller's report on water privatisation is noteworthy, accusing the Special Rapporteur of infringements on the Code of Conduct for Special Procedures Mandate-holders of the Human Rights Council. These accusations were brought forth by the well-known lobby organisation Aquafed with members such as Veolia, Suez and FCC Aqualia (Devex, 2020).

vest their resources to influence institutional change or improve their competitiveness (Turnheim & Sovacool, 2020). At this point, a "regime fragmentation" could occur (Turnheim & Sovacool, 2020), which would favour the emergence of windows of opportunity for the breakthrough of sustainable alternatives. The extent to which the above strategies can be successful is uncertain due to the specificities of the water sector. So far, water-sensitive solutions lie outside of the capability portfolio of the large firms so that investing in alternative solutions would undermine their core business model which is build around large infrastructure.

According to Geels and Schot's (2007) reconfiguration pathway of regime transformation, the trajectory of the regime could also change when the incumbents adjust their strategies based on the successful application of niche innovations in local contexts. Here, it becomes crucial to identify appropriate intervention points. In this context, cities are considered to play a central role (Fuenfschilling, Frantzeskaki, & Coenen, 2019), although they have not yet been sufficiently studied as a place for sustainability transitions (Ehnert et al., 2018).[18] While the need for sustainability transitions is particularly visible in cities, initiatives that address unsustainable behaviours are developing mainly in urban areas (Fuenfschilling & Truffer, 2016). Therefore, the importance of urban experimentation is great (Fuenfschilling & Truffer, 2016). Based on the above analysis, cities characterised by a high degree of MNCs or hosting several MNCs could be considered as possible locations for the establishment of model solutions due to their structural power within the regime. In reality, however, it can be observed that model projects in cities with a central regime position are overrun by global regime logics, as happened in the case of Beijing (Neighbour & Qi, 2018). Once, Beijing has been considered a potential place for the emergence of an on-site treatment industry which the potential of challenging the dominant logic of the water sector (2016). However, it has since abandoned the idea of on-site reuse, as local companies have refocused on large-scale infrastructure (Neighbour & Qi, 2018). In this sense, the focus might be re-directed to lighthouse projects in cities with a weaker regime presence such as San Francisco.[19] Taking into account the transnational nature of sustainability transitions, policy efforts here could focus on building global city networks between such "lighthouse cities" and cities that are not yet part of the global regime, with the ultimate goal of nurturing a global niche (Fuenfschilling, Frantzeskaki, & Coenen, 2019). Given the inertia and complexity of the infrastructure sector in general and the water sector in particular, this raises the question of which actors within cities can implement such networking and sustainability efforts (Sengers, Wieczorek, & Raven, 2019).

6.3 Sustainability Transitions outside the Global Regime

Another opportunity for a sustainability transition in the water sector is the development of alternative rationalities in regions that are not part of the sector's GPN and therefore not under the influence of the global socio-technical regime. In the case of the water sector, large parts of the world are not yet part of the corporate network, which is especially true for regions in developing countries and the BRICS states. Faced with the challenges of population growth and urbanisation, Latin American, Asian and especially African cities will be increasingly concerned with how to provide water infrastructure in the future. Since, according to Markard (2011), sustainabil-

[18] A special issue introduced by Fuenfschilling et al. (2019) is dedicated to the relation between urban experimentation and the (de-)institutionalization of socio-technical configurations.

[19] As of 2015, San Francisco mandated that all new large buildings build on-site water recycling facilities to treat their non-potable water, in order to create a new paradigm of water provision within the city (Global Opportunity Explorer, 2020).

ity efforts should focus on regions where infrastructure is still being developed and alternative technologies can mature, these regions could represent valuable starting points for a diffusion of innovations from the "Global South" to the "Global North".

In this sense, interesting perspectives have emerged. While it is generally agreed on that regimes in developing countries are less institutionalised and thus more conducive to changes in regime rationalities, some authors have argued that a certain degree of regime stability needs to be present to initiate the development of niche innovations and alternative solutions (Hansen et al., 2018). Depending on the sector, this consideration makes certain developing regions more suitable for sustainability initiatives than others, in the water sector bringing into fore cities where the corporate network is present albeit to a small extent. The BRICS countries in particular, with the exception of China, could be interesting in this context, as they represent weak points in the regime and at the same time have the financial resources to develop and build up alternative industries. In South Africa, Durban could be relevant in that it can be considered a centre of innovation in the water sector through the installation of water recycling plants and being a testing ground for non-sewered on-site wastewater systems (eThekwini Municipality, n.d. Sutherland et al., 2021). Other exemplary cities in the developing African context are cities such as Abidjan, Accra, Casablanca and Windhoek with an *indegree* of one indicating a weak regime presence.

Another debate focuses on the differences in building a niche industry versus implementing individual projects (Hansen et al., 2018). While it is common to implement single projects to demonstrate the functionality of an alternative solution, these often fail to have a major impact due to a lack of cross-scale coordination (Hansen et al., 2018). To counteract this, long-term programmatic approaches should be pursued across different scales, consisting of interlinked and coordinated sustainability experiments (Hansen et al., 2018). Here, collaborative networks between "lighthouse" cities and cities in the process of implementing urban infrastructure could be conducive to nurturing the global niche around alternative water solutions. While it remains crucial to maintain sustainability initiatives as locally driven, such transnational linkages support local capacity building, connect actors across scales and can thus contribute to the emergence of mature niches (Sengers, Wieczorek, & Raven, 2019). Again, in addition to transnational cooperation, national policies are needed to shield the cities involved from the influence of MNCs as they will seize the promising opportunity to build and operate a completely new urban water infrastructure. To this end, INGOs and development banks need to continue reorienting themselves towards carefully considering the involvement of MNCs in their funded infrastructure projects.

7 Conclusion

Based on the observation that infrastructure sectors in particular face problems regarding the environmental sustainability of their traditional solutions, while alternative solutions exist but are not widely adopted, this thesis has explored barriers to sustainability transitions. Drawing on the understanding that the stability and inertia of socio-technical systems is sustained by different actors and elements across multiple scales, this thesis has considered the transnationality of sustainability transitions. Taking a spatially sensitive perspective, the role of private actors within global regime structures has been analysed in order to contribute to the empirical understanding of dynamics within global regimes. To do so, private actor structures within an exemplary global socio-technical regime have been characterized.

As an extreme case with clear regime structures, the water sector was chosen as a case study and subsequently analysed using concepts of SNA. After identifying the most influential MNCs in the water sector, a spatial mapping and characterisation of corporate network structures were combined with a regional analysis of spatial strategies. The analysis was then extended by identifying spatial interlocks between companies and visualising the locations of consulting and engineering firms active in the water sector. This approach has revealed an international actor-network that enables the diffusion of dominant rationalities across the globe and accounts for the similarities of infrastructure solutions in various regions. The compact, hierarchical and global-spanning corporate network of the water sector implies an easy and fast diffusion of information and regime rationalities throughout the global regime. As particularly influential actors, the French companies Veolia and Suez have been identified, which stand out in terms of the number of subsidiaries and their spatial spread across the world. In addition to the dominant actors, places like Paris, Beijing, Madrid and Singapore were identified as strong spots within the global regime where it will be almost impossible for alternative solutions to succeed. At the same time, regions that represent weak spots in the regime or are completely peripheral to it were identified as optimal points for policy intervention.

With regard to the research question, of *How do corporate network structures influence the transformative capacity of a global regime?*, this thesis has revealed that depending on the nature of the network, corporate network structures can be highly obstructive for sustainability transitions. In particular, a global corporate network dominated by a handful of key actors contributes to regime stability by institutionalising its favoured rationalities in different regions of the world. The existence of a global regime with such characteristics will first of all require a close examination of the regime structures, before policy efforts are targeted at different scales, coordinated across scales and collectively led.

Considering that the adoption and diffusion of alternative solutions requires a change in global regime structures in such a way that alternative solutions and peripheral actors move into the core of the regime, sustainability transitions can be initiated within and outside the current regime. To this end, a shift of destabilisation pressure to the global level through the reorientation of supranational actors such as INGOs and development banks will be crucial. In relation to transitions within the current regimes, re-framing activities of large donors or governments could provide an incentive for incumbents to engage in the development of sustainable alternatives. Likewise, model regions and "lighthouse projects" should be established and supported in weak spots of the regime. Together with regions that are still outside the global regime, these places could build city networks and nurture a global niche that could eventually be mature enough to challenge the global regime. Shielding these regions from the pressure of global regime actors will be necessary here. With regard to sustainability transitions outside the global regime, the analysis has highlighted developing countries and large parts of the BRICS countries as suitable places for the development of an alternative industry.

With these findings, the paper provides one of the first empirical underpinnings of a global actor network in a global socio-technical regime. By identifying structural power relations within a network configuration, the insights further contribute to the conceptualisation of the global regime framework. Applying SNA to private regime actors has not only confirmed the clear multiscalar nature of the regime, but has also shown that the method is suitable for characterising economic sectors in detail and highlighting places where sustainability policies are most likely to have a major impact. The thesis has also demonstrated that the identification of the network structure allows to distinguish between certain types of policies that could be more or less conducive to achieving a change in rationalities not only in a specific context, but in a global regime as a whole.

Due to the scope of this thesis, however, a variety of aspects could not be considered, but should be the subject of future research. First of all, it would be reasonable to include public utilities in the analysis, as they represent the majority of service providers worldwide, at least in industrialised countries (Fuenfschilling & Truffer, 2014). Similar to the private utilities, the public companies diffuse traditional "hydraulic logic" solutions by working closely with development banks, consultancies and engineering firms. A joint analysis of the private and public structure would therefore provide a richer picture of the global regime of the water sector. Second, while the use of majority ownership in the selection of subsidiaries ensures the interpretation of regime rationales that diffuse from the headquarters location to the entire network, the analysis does not allow, for example, the identification of network clusters. However, with the right data and sufficient resources, such an analysis would be meaningful as the regional strategies of MNCs could be examined in more detail. Lastly, the above analysis does not distinguish between more or less important relationships between headquarters and subsidiaries and thereby runs the risk of under- or overemphasising certain locations. An analysis that succeeds in quantifying the linkages between headquarters and subsidiaries would certainly provide insights beyond those of this thesis.

Independently of the analysis of this thesis, in order to further enrich research on global socio-technical regimes, case studies should be used to investigate how different scales interact with the global socio-technical regime of a sector. Of particular interest here is which actors, at which scale and to what extent they can create a tension in the current regime structure. It is conceivable that other geographical scales besides cities may also prove to be suitable places for sustainability transitions to occur. In this regard, it should be especially worthwhile to examine places that have successfully pursued alternative paths of transformation despite the existence of powerful regime structures. Similarly, research should focus on the interactions of MNCs with the local context to further improve the local embeddedness of foreign subsidiaries to enable alternative strategies. Furthermore, as shown in the case of Veolia and Suez, a global regime is not a homogeneous construct; on the contrary, rivalries and competition persist. The study of patterns of cooperation and conflict is promising for gaining further insights into policy intervention points. Finally, analyses of global regime structures for other sectors could enable the comparison of sustainability transitions in different contexts. Identifying commonalities and differences can provide a starting point for more general policy recommendations and facilitate their application for policymakers.

In conclusion, the conceptualisation of a global regime has been a first important step in recognising the interconnected and transnational nature of the globalised economy. However, the task now will be to analyse these structures in different contexts in order to contribute to the much needed social and industrial transformation towards a more sustainable society. While history has shown that transitions to sustainability are possible, today it is crucial to accelerate the transition processes as the time until humanity has crossed all planetary boundaries is rapidly running out. This requires continuous and joint efforts by researchers from different disciplines and policymakers. Recognising the global nature of sustainability transitions, with barriers across different scales, should be central here.

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Appendix

Table A1 Contextual information about the water MNCs.

	Short description	**Role in the water sector**
Suez	Holding engaged in the area of environmental services	Provision of services in the areas of water and waste → in the water sector covering drinking water and wastewater treatment services by constructing water treatment facilities, supplying water and providing wastewater treatment activities
Veolia	Optimized resource management group	Design and provision of water, waste and energy management solutions → in the water sector covering potable water plants and supply systems, wastewater systems and treatment plants
Beijing Enterprise Water	Investment holding company	Active in the water sector through the construction and operation of water treatment plants, construction of seawater desalination plants, water provision, consultancy services, sales of machinery and technical knowledge
VA Tech Wabag	Holding company	Active in the water sector through the design, supply, installation, construction and operational management of drinking water, wastewater treatment, industrial water treatment and desalination plants
Acciona Aqua	Ultimate owner is the holding company Acciona SA	Active in the water sector through the construction of desalination and water treatment plants, drinking water stations and the management of the water cycle process
FCC Aqualia	Ultimate owner is the waste management company FCC	Active throughout the process of the water management cycle ranging from the supply of drinking water to the treatment of wastewater
Manila Water	Ultimate owner is the Ayala Corporation	Provision of water, sewerage, sanitation and distribution services, pipework and management services
China Everbright Water	Investment holding company	Active in the water sector through wastewater treatment, water supply, research and development of water environment technologies
Remondis Aqua	Ultimate owner is Remondis belonging to the Rethmann Group	Provision of municipal and industrial water management services → water supply, wastewater treatment and sewage sludge recycling
Eranove	Amenities group	Active in the water sector through the management of water resources and the production of drinking water
Xylem	Water technology company	Equipment and service provider for water and wastewater application offering various production and services addressing the whole water cycle
Aquatech	Water purification corporation	Design and manufacturing of water and wastewater treatment systems focusing on desalination and water reuse

Note: Information taken from Reuters (2021) company profiles. Information for FCC Aqualia, Remondis Aqua, Eranove and Aquatech extracted from the companies' websites.

Table A2 Contextual information about the engineering and consulting companies.

	Short description	**Role in the water sector**
AECOM	Global infrastructure consulting company	Provision of planning, consulting, architectural and engineering design and construction management services in end markets such as water
Jacobs	Engineering group	Buildings, Infrastructure and Advanced Facilities segment active in the provision of services to the water sector
Black & Veatch	Global engineering, consulting and construction company	Active in infrastructure development including the water sector by providing design, procurement and construction services
WSP	Professional services company	Offering services in project delivery and consulting, involved in the development of water infrastructure through analysing, designing and managing projects
Mott MacDonald	Engineering, management and development consultancy	Technical advisory services in water supply, wastewater recycling and water management

Note: Information taken from Reuters (2021) company profiles. Information for Black & Veatch and Mott MacDonald extracted from the companies' websites.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

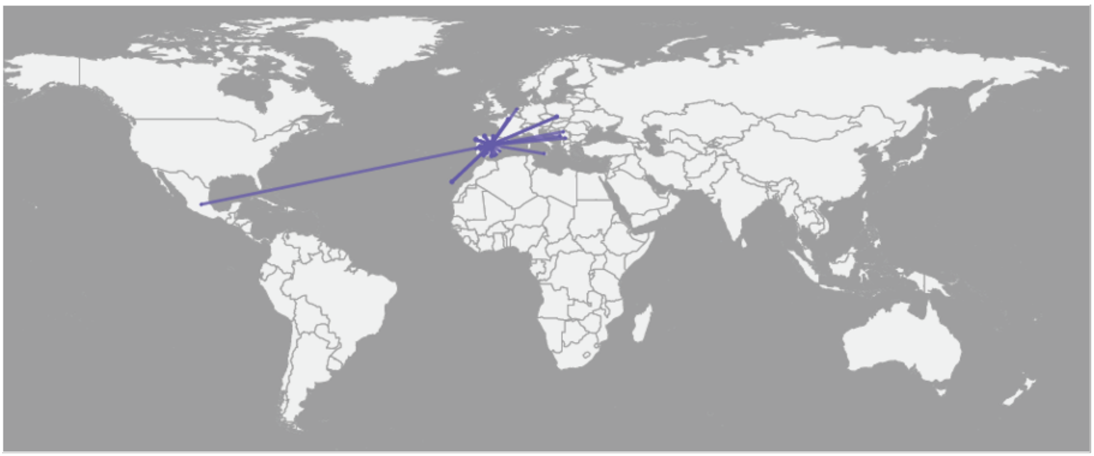
Figure A1 Corporate network of Beijing Enterprise Water.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A2 Corporate network of VA Tech Wabag.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A3 Corporate network of Acciona Aqua.



Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A4 Corporate network of FCC Aqualia.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A5 Corporate network of Manila Water.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A6 Corporate Network of China Everbright Water.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

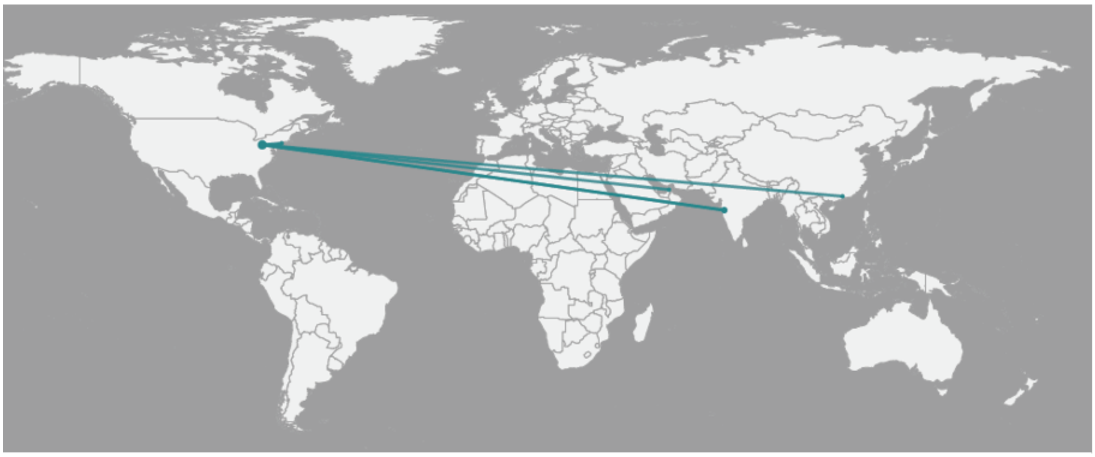
Figure A7 Corporate network of Remondis Aqua.

Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A8 Corporate network of Eranove.

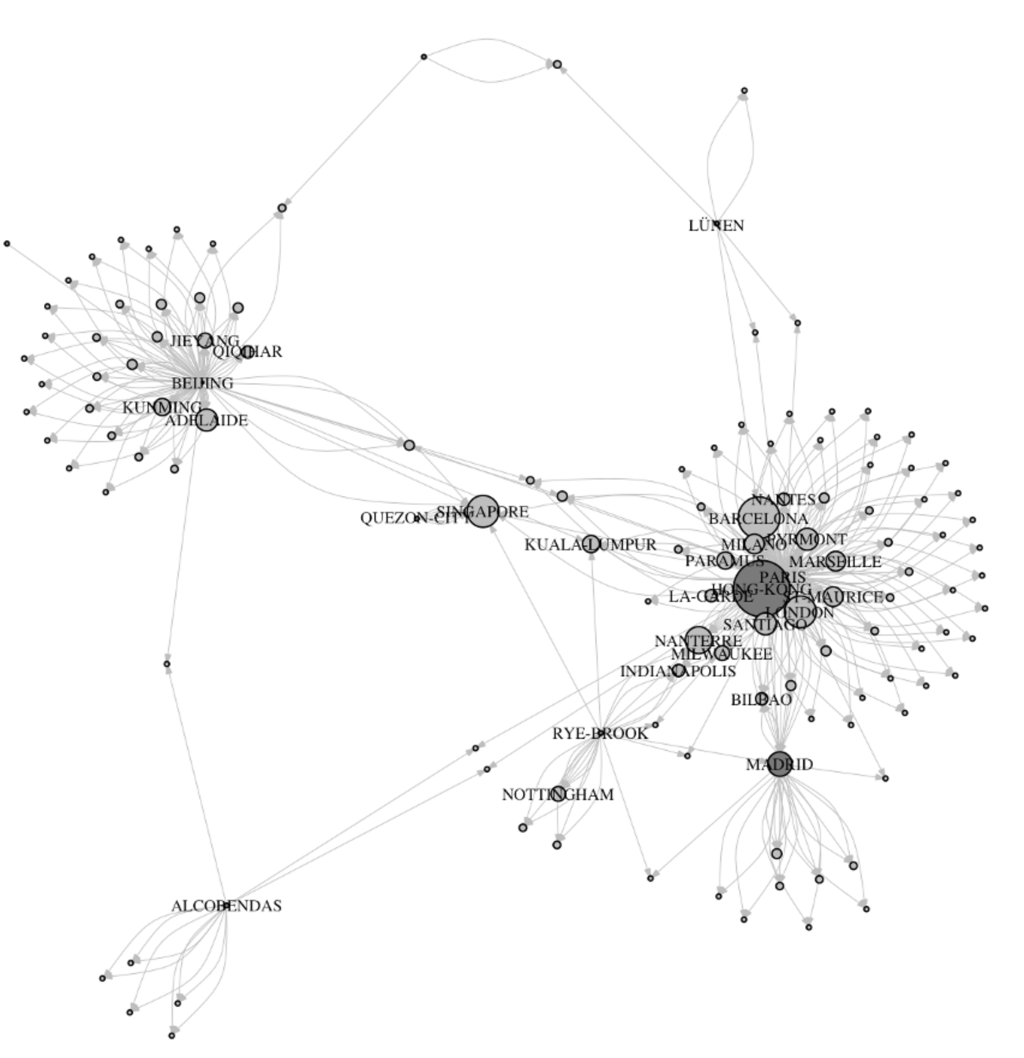
Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A9 Corporate network of Xylem.



Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A10 Corporate network of Aquatech.



Note: Author's own visualisation based on data from Orbis (Bureau van Dijk, 2021).

Figure A11 Depiction of the one-mode city-city network with headquarter locations in darkgrey and node size relative to the *indegree*. For better visibility, locations with a *degree* of 1 are excluded from the illustration.