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The Geography of Technology Legitimation

How multi-scalar legitimation processes matter for path creation in emerging industries

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Abstract

Research in economic geography has recently been challenged to adopt more institutional and multi-scalar perspectives on industrial path development. This paper contributes to this debate by integrating insights from (evolutionary) economic geography, as well as transition and innovation studies into a conceptual framework of how path creation in emerging industries depends on the availability of both knowledge and legitimacy. Unlike the extant literature, we argue here, that not only the former but also the latter may substantially depend on non-local sources, which hithero have largely been overseen. Conceptually, we distinguish between multi-scalar export, attraction and absorption of legitimacy. Coupled with conventional knowledge indicators, this approach enables us to reconstruct how not only external knowledge sourcing but also multi-scalar institutional dynamics contribute to countries' ability to leverage the potential of different path creation constellations in an emerging industry. Methodologically, we develop legitimation indicators from a global media database, which was built around the case of modular water technologies. Cross-comparing the evidence from six key countries (India, Israel, Singapore, South Africa, UK, USA) with differing path creation constellations allows us to hypothesize how multi-scalar legitimation influences a country's prospects for creating a radically new industrial path.

Evolutionary economic geography, path creation; legitimation; institutional dynamics; multi-scalarity; modular water technologies

1. Introduction

Research in economic geography (EG) has recently advocated for institutional and multi-scalar perspectives on path development and diversification processes (Boschma et al., 2017, MacKinnon et al., 2018, Hassink et al., 2019). Among others, scholars have started to analyse the role of institutional agency in shaping industrial path creation (see e.g. Grillitsch and Sotarauta, 2019, Isaksen et al., 2018, Sotarauta and Suvinen, 2018, Dawley, 2014), embracing the idea of path creation as a process of mindful deviation not only from technological and knowledge artefacts but also from the relevant institutional structures (Garud and Karnøe, 2001). This work has convincingly shown that distributed system building processes, drawing on policy interventions, institutional entrepreneurship and strategic resource mobilization play a key role for path development, largely on par with related knowledge and skill sets (Carvalho and Vale, 2018, Binz et al., 2016b, Dawley, 2014, Garud et al., 2010, Garud and Karnoe, 2003).

Largely in parallel, transition studies have conceptualized in depth how the co-evolution of institutional dynamics and technological innovation influence the development potentials of new industrial paths. They elaborated how institutions-oriented agency can provide breeding grounds for newly emerging socio-technical configurations (Hoogma et al., 2002, Schot and Geels, 2008), and what kind of institutional and technological alignment processes have to happen for emerging industries to scale and mainstream (for instance as depicted in the literature on technological innovation systems, see Hekkert, 2007, Bergek et al., 2008a, Markard, 2018). This concerns, the co-evolution of new technologies and their markets (Quitzow et al., 2014, Dewald and Truffer, 2012, Dewald and Truffer, 2011) or how technology legitimation influences development trajectories of new industries (Bork et al., 2015, Markard et al., 2016, Binz et al., 2016a). Based on insights from this "institutional turn" in transition

studies (Fuenfschilling, 2019), this paper seeks to improve and complement the hitherto spatially undifferentiated understanding of the institutional underpinnings of path creation in EG.

One of the hallmarks of transitions literature is the distinction between innovation processes in well-established sectors (socio-technical regimes) and emerging industries that are new to the world (socio-technical niches) (Markard et al., 2012, Geels, 2002). Boschma et al. (2017) recently used this distinction to further conceptualize the institutional dynamics that enable path development processes in 'new-to-the-region' and 'new-to-the-world' industries. Particularly in new-to-the-world industries (emerging industries in the remainder), where technology development, product profiling, and user preferences have to be aligned for the first time, the ability to institutionally embed and thus legitimize an emerging industry becomes a crucial determinant of successful path creation. Respective industries are often, but not exclusively, found in the context of infrastructure sectors (e.g. transport, ICT), around innovations addressing grand challenges (e.g. renewable energies), or among emerging platform-based industries (e.g. Uber) (Coenen et al., 2015, Pelzer et al., 2019, Trippl et al., 2020).

In innovation and transition studies, legitimation has been conceptualized as the process by which proponents of a technology attempt to align norms, values and beliefs in favour of their proposed solutions (Markard et al., 2016, Binz et al., 2016a, Bergek et al., 2008a, Hekkert, 2007). Our framework draws on this interpretation but contests the often implicit assumption that the relevant institutional processes are limited to regional or national boundaries. Recent contributions hint at the multi-scalar nature of legitimation processes for emerging industries, e.g. through the adoption of non-local narratives and policies, or the attraction of external investors and industry advocates (Sengers and Raven, 2015, Späth and Rohracher, 2012, Binz et al., 2016b, Crevoisier and Jeannerat, 2009, Quitzow, 2015).

Building on these insights, we propose a set of generic, multi-scalar mechanisms, through which industry legitimation may be generated by drawing on local and/or non-local sources enacted by actors at different spatial-scales. More specifically, we look at i) genuine *endogenous legitimation* within a region / country, ii) the mobilization of legitimacy from external sources (*absorption*), iii) the *attraction* of external actors contributing to local legitimation , and vi) the *export* of legitimacy by local industry proponents.

The institutional capability of a region or country to leverage these processes, may be crucial for its path creation prospects (Malmberg and Maskell, 1997). We will elaborate this argument by developing a typology of different path creation constellations that depend on pre-existing knowledge and capabilities on the one hand, and legitimacy for an emerging industrial path on the other hand. With help of our empirical analysis, we show how countries with varying path creation constellations position themselves in the global legitimation geography, allowing us to create hypotheses on how multi-scalar legitimation processes may contribute to regional path creation potentials.

Empirically, we focus on the case of a new industrial path that is currently evolving around modular water technologies (called "*modular technologies"* in the remainder"). The modular water industry is still in an emerging development phase globally, challenging the widely established regime around conventional, centralized wastewater treatment (referred to as "*conventional technologies*" from now on) (Fuenfschilling and Binz, 2018). To empirically assess the relevant legitimation dynamics, we propose a mixed method approach, which builds on a database of newspaper articles (Nexis Uni). Over 180 English-language newspapers and industry magazines were selected, in order to identify articles dealing with water and sanitation problems for an eight year period (2011-2018). The selected articles were coded with a socio-technical network analysis heuristics (Heiberg et al., 2020) and then analyzed with novel indicators for the relevance of multi-scalar technology legitimation processes. By coupling

these legitimation measures with patent data as well as information on path dependencies in built infrastructures, we arrive at a typology of generic path creation constellations. Eventually, we assess to what extent multi-scalar legitimation processes are used in leveraging the potentials of different path creation constellations.

Our results show considerable variation in these constellations. The most salient cases can be characterized as follows: The US path creation configuration can be characterized as a *lead market constellation*, which combines well-developed local knowledge and capabilities with rather weak institutional path dependencies. With similar knowledge capabilities but facing a locked-in socio-technical regime, Israel and Singapore signify *export oriented constellations*. India and South Africa, in turn, represent cases with rather weak knowledge and capability stocks, but also weak path dependencies and strong environmental problem pressures, thus exemplifying *challenge-driven path creation constellations*. The UK, eventually, faces a *regime lock-in constellation* associated with a strong regime and only modestly established knowledge and capabilities. In these different constellations, we find that countries engage in the multi-scalar mobilisation of legitimacy to a varying degree, enabling the formulation of hypotheses on how these processes support or hinder industrial path creation more generally.

The argument of the paper will be elaborated in the following steps. Section 2 will review the industrial path creation literature and draw on recent insights form transitions- and innovation studies regarding the multi-scalar nature of emerging industry legitimation. Based on this, we propose an integrated framework of different types of path creation constellations for which multi-scalar legitimation processes may matter. In section 3, we apply this framework to the case of path creation around modular water technologies and introduce our methods. The results are presented in section 4. Section 5 discusses insights, conceptual implications and limitations of our research before concluding with an outlook on avenues for future research.

2. Conceptualizing the contribution of multi-scalar legitimation to industrial path creation

The literature on industrial path development in evolutionary economic geography and regional studies has paid comparatively little attention to institutional factors such as social, cultural and normative context conditions for emerging economic activities (MacKinnon et al., 2009, Hassink et al., 2014, Hassink et al., 2019). Attempts investigating institutional preconditions to path creation have furthermore chosen rather macro-level and static approaches such as Boschma and Capone (2015) who apply a Varieties of Capitalism (VoC) lens to study how macro-economic structures in coordinated and liberal market economies lead to different industrial diversification patterns. Critics of this approach have called for a more explicit consideration of process-based and micro-institutional approaches associated with path development trajectories (see e.g. Isaksen et al., 2018, Sotarauta and Suvinen, 2018, Zukauskaite et al., 2017, Dawley, 2014).

The role of distributed and embedded agency in emerging industries was introduced most prominently by Garud and Karnoe (2003). They proposed to conceptualize it as the continuous re-combination of regionally available codified and tacit knowledge stocks by a heterogeneous set of actors, leading to different national innovation trajectories, labeled as science-technology-innovation-based 'breakthrough' or doing-using-interaction-based 'bricolage'. Carvalho and Vale (2018), in a recent paper, show how the latter process led to unrelated diversification in the biotechnology sector in a peripheral Portuguese region with comparatively weak initial knowledge and skill endowments. They conclude that path development was not facilitated by technological or knowledge relatedness but rather by "institutional relatedness" (see also Content and Frenken, 2016). Also Binz et al. (2016b) showed how a new water recycling

industry emerged in Beijing through a process of "anchoring and system building", which allowed local actors to outcompete rivalling initiatives in other regions that were initially endowed with stronger related variety (Xi'an and Shanghai).

A similar agency-based approach was suggested by Grillitsch and Sotarauta (2019) who argue that change agency for path development is not limited to technology entrepreneurship but also includes "institutional entrepreneurship", and "place leadership". While institutional entrepreneurship relates to active processes of institutionalizing new or transforming existing institutions (Battilana et al., 2009), place leadership is more concerned with the alignment of various actors to jointly mobilize resources in favour of a certain path development trajectory (Gibney et al., 2009).

Despite an increased acknowledgement of the role of institutional dynamics in industrial path creation, the related conceptualizations (around broad notions like institutional thickness, system-level agency or institutional entrepreneurship) have remained somewhat vague on the relevant factors and mechanisms that condition the emergence of radically novel industries. This is why we propose a closer connection to transition studies, which have used socio-technical regimes and technology legitimation as proxy measures for assessing the institutional path-dependencies and dynamics that make an emerging industry comply with existing institutions or adapt the institutional environment in a region to such a degree that it becomes more supportive of the emerging industrial path (Markard et al., 2016, Binz et al., 2016a, Geels and Verhees, 2011, Bergek et al., 2008b, Aldrich and Fiol, 1994).

2.1 Legitimation as a focal lens to understand institutional dynamics around path creation

An important qualification in economic geography is that emerging industries are embedded in two relevant institutional contexts; a regional and a sectorial one (Boschma et al. 2017). While economic geography is predominantly concerned with the regulative, normative and cultural-

cognitive structures in a region that support or hinder innovation, transitions research focusses on understanding how the (inherently multi-scalar) socio-technical systems that fulfill societal functions (energy, water, transport, agro-food) are built, maintained and potentially replaced (Rip and Kemp, 1998). A core of this literature deals with explaining how path dependencies can be assessed through the concept of socio-technical regimes. These are defined as highly institutionalized configurations of knowledge, practices, technologies, products, user needs, regulation, institutions and infrastructures which co-evolve and get aligned over time, thus locking sectors into path-dependent development trajectories over expanded time spans (ibid.). Sectors with strongly institutionalized regimes are less open for radically novel paths. At the same time, transitions scholars have elaborated in much detail, how such path dependencies may vary between different regions and be broken up through distributed and system-level agency – as in the technological innovation systems (TIS) framework, (Bergek et al., 2008a, Hansen and Coenen, 2015, Markard et al., 2016), or socio-technical alignment and scaling processes happening in protective spaces, so called socio-technical niches (Rip and Kemp, 1998, Geels and Raven, 2006).

Similar to the notions of agency in the path development literature, transition studies emphasize the importance of collective, more or less coordinated strategies, mobilizing various emerging system resources for successful innovation. Binz et al. (2016b) argue that four key system resources have to be mobilized in a region to enable path creation processes; knowledge, markets, financial investment and legitimacy. Especially for emerging industries that have no predecessor in the social order, the mobilization of legitimacy is arguably of key importance (Aldrich and Fiol, 1994; Rao 2002). Legitimacy is commonly defined as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995: 574). It thus denotes a societal assessment of how well an emerging industry is aligned with the

relevant regional and sectorial institutional contexts (Markard et al. 2016). If an industry is well-aligned, the relevant audiences will take it for granted and confer resources to its further development, be it in the form of policy support, the installation of test markets, the provision of educational services, venture capital or even through the absence of organized opposition form citizen's movements.

If it is in conflict, the industry's proponents will have to engage in active institutional work to change the relevant structures in favour of the new organizational form (Lawrence and Suddaby, 2006). The actor strategies that aim at changing the relevant institutional contexts often comprise rather subtle and discursive interventions in the social order, e.g. through the construction of new identities and norms, changing normative associations or educating relevant audiences about the benefits of a new solution (Lawrence and Suddaby, 2006, Fuenfschilling and Truffer, 2016). Such interventions are 'embedded' in the sense that they are both enabled and constrained by the institutional structures that they, themselves attempt to influence (Battilana et al., 2009, Garud and Karnoe, 2003). Over time, system resource mobilization and institutional work activities will adapt the relevant institutional contexts to such a degree that legitimacy for the emerging industry is created and/or the legitimacy of the pre-existing path is eroded (Rao, 2004, Battilana et al., 2009, Fuenfschilling and Truffer, 2016, Binz et al., 2016a, Markard et al., 2016).

Linking such observations back to the path creation and diversification literature, Boschma et al. (2017) have, on one hand, argued that institutional work, and technology legitimation, are particularly important in cases of unrelated diversification where actors have to engage in distributed, bricolage-type of agency to overcome place dependencies stemming from the set of existing (or missing) resources in a region. On the other hand, institutional work and legitimation are crucial especially for newly emerging industries that have to overcome the path dependency emanating from a deeply institutionalized socio-technical regime in a sector. From

a geographical point of view, both overcoming place-dependencies and sectorial path dependency may involve active institutional work at the local level, but at the same time require the mobilization of the local resource-base or the challenging of the dominant regime in a sector (which often develops in international networks) through multi-scalar forms of institutional work (Fuenfschilling and Binz, 2018). Following this reasoning, technology legitimation, becomes an umbrella term for various types of institutional work, which may be enacted by local or non-local actors at different spatial scales and in in different places.

We will now elaborate how multi-scalarity has been conceptualized in path creation research so far and how existing perspectives have to be extended for grasping path creation processes around emerging industries.

2.2 Non-local sources of path creation

Scholars in EEG have only recently started to systematically consider the importance of non-local knowledge as a source of path creation and diversification (Trippl et al., 2017, Boschma et al., 2017, Neffke et al., 2018, Klement and Strambach, 2019). Already in their seminal article, Martin and Sunley (2006) highlighted that new paths may emerge from the importation of organisational forms, technologies, firms, or institutional arrangements form other places. However, it remained unclear how exactly the importation of institutional arrangements would play out and whether and how it resembles the sourcing of non-local knowledge.

In order to tackle this challenge, we build on a recent framework on how external sources of knowledge can contribute to regional industrial path development proposed by Trippl et al. (2017). Their heuristic separates the anchoring of non-local knowledge for path development into the *attraction* of new actors from outside a region and the *absorption* of non-local knowledge through more intangible linkages. The former relates to the inflow of new organisations or individuals, e.g. through labour migration, the resettlement of firms, takeovers, mergers or foreign direct investments (FDI). The latter does not require actors to relocate but

rather relates to formal or informal linkages between organisations or individuals based on different types of non-spatial proximities that facilitate knowledge diffusion (Bathelt et al., 2004, Agrawal et al., 2006).

Building on this differentiation, Trippl et al. (2017) argue that " *the need and attractiveness for exogenous actors/resources as well as the absorptive capacity to turn those into new growth paths*" (p.692) are the most crucial determinants of the importance and role of non-local resources in path creation processes. Attractiveness reflects the capacity of a region to draw in knowledge carriers such as individuals or organisations, e.g. through local assets such as a relevant skill-base, education, security, more competitive salaries or other regional amenities. Absorptive capacity, in contrast, reflects the ability of "anchoring*"* (Crevoisier and Jeannerat, 2009) non-local, mobile knowledge into a locally embedded path.

We propose to conceptualize the non-local relationships that impact legitimacy for an emerging industrial path in a region along similar lines, drawing on recent insights from transition studies. Transition scholars argue that legitimacy in a region may be fuelled by trade or collaboration networks, when entrepreneurs absorb success stories from abroad, or when they invite external actors to contribute to solving local problems. These mechanisms were shown to be particularly relevant for clean tech industries in emerging economies (de Lange, 2016, Quitzow, 2015). The Chinese PV industry, for example, initially almost completely legitimized itself through overseas export successes and listings at international stock exchanges (Binz and Anadon, 2018, Zhang and White, 2016). A study on the global diffusion of Bus Rapid Transport (BRT) systems (Sengers and Raven (2015)) similarly finds that "places" can be mobilized by a global community of actors who use success stories of certain cities in globally disseminated policy documents to push infrastructure projects in various regions. Späth and Rohracher (2010, 2012) relate to discourse coalitions in emerging renewable energy paths to show how Austrian actors absorbed national and international narratives purposefully by translating and using them in

specific regional contexts. Through the absorption of these non-local narratives, they managed to align other actors' technological choices across governance levels in Austria.

These insights suggest that attraction and absorption processes are relevant not only for knowledge, but also legitimation dynamics. Of course, emerging industries may also predominantly draw on legitimacy that is built up endogenously inside a regional context, like in case of the Danish wind turbine industry (Garud and Karnoe 2003). Yet, as recent literature shows, the wind power case is arguably also quite special in that its innovation and institutional embedding processes depended particularly strongly on spatial proximity (Binz and Truffer, 2017, Huenteler et al., 2016). In other industries, multi-scalar linkages may be much more relevant for the buildup of industry legitimacy. We can therefore conceptualize multi-scalar legitimation interactions in three generic ways (Fig. 1).

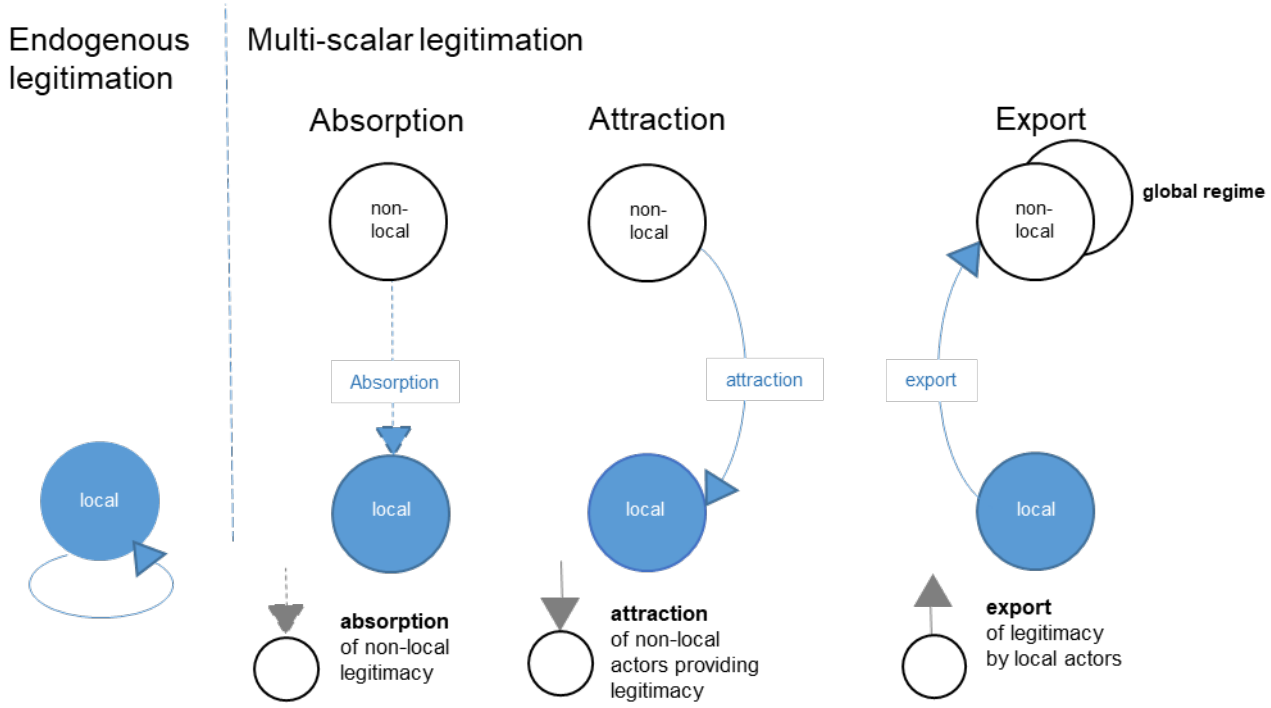


Fig. 1 Multi-scalar legitimation processes. Own figure

"Absorption" relates to a situation in which regional actors internalize legitimacy from other places. This mostly happens through reference to success or failure cases in other parts of the

world. For instance, the early legitimation of bus rapid transport (BRT) systems in several South East Asian cities, was strongly driven by the absorption of the emblematic "success case" of Bogota, Colombia (Sengers and Raven, 2015). In this process, supportive narratives were transported between places not only through mobile actors, but by other forms of communication such as media, expert journals or informal communications at industry events, etc.

"Attraction" refers to legitimation that is built up by external actors that try to create conducive market environments for their exports in the respective region. From the region's perspective, this can refer to a rather passive condition, e.g. when a region presents itself as a promising target market for new technologies, or more pro-actively when local actors try to actively construct conducive institutional framework conditions for external firms to operate in the region. An example for a rather passive strategy is Norway which strategically developed into the current global lead market in electric vehicles, by leveraging strong deployment policies and its almost exclusive electricity generation portfolio from hydropower plants (Ryghaug and Skjølsvold, 2019), laying the foundation for the development of a novel industry around battery development in the Agder region (Barbiroglio, 2020). Examples for more proactive attraction strategies abound in the catchup literature, for instance when latecomer regions proactively attract foreign direct investments or participate in technology transfer programs by international organizations (Gosens et al., 2015, Yeung, 2016).

As the mirror image of attraction, we may expect to see legitimation activities that draw on a pronounced export strategy. "Export" refers to a state in which legitimacy is not primarily achieved by endogenous institutional embedding, but which aims at supporting an emerging regional industry by serving markets and influencing institutional environments outside the home region. The platform-economy company Uber, who actively attempted to legitimize its service Uber pop in various world cities at once while de-legitimizing the existing regulations

around Taxi laws constitutes an illustrative example (Pelzer et al., 2019). Export to other regions may at the same time coincide with absorption, i.e. when narratives about export success help to mobilize indigenous resources such as export risk insurance, industrial support policies or local venture capital. An illustration is the case of the early Chinese solar power industry, which invested heavily in obtaining international quality certificates for overseas mass markets (Binz and Anadon, 2018). Success in export markets was then used to legitimize the industry in the domestic context, where knowledge capabilities and market formation were originally rather limited.

Based on these specifications, we propose to conceptualize the trans-regional flows of legitimacy in similar terms as the trans-regional knowledge flows identified by Trippl et al. (2017). However, the embedding in institutional contexts implies a somewhat more complex conceptualization of multi-scalarity. Most prominently, we have to account for institutional contexts established at different "scales", such as regional, national and global scale, while acknowledging that these levels are intertwined and imbricated. For the case of legitimation, it is particularly important to understand that socio-technical regime structures relate to the dominant institutional structures in sectors, which often reach beyond single regions or countries, up to a global scale (Fünfschilling and Binz, 2018). Regime structures are predominantly developed, maintained and changed by (international) expert networks in a sector and may shape the way national or regional industrial strategies can be carried out, in particular when it comes to radically new approaches. At the same time, the socio-political and cultural legacies in regions and countries lead to strong spatial variation in regimes as global regime structures being only partially or 'creatively' translated back into regional and national settings. The challenge to legitimize emerging industries is thus dual in that it needs to tackle the place-dependency in regional/national institutional structures, as well as path-dependencies in international sectorial structures (Boschma et al., 2017). We have to acknowledge the multi-

layered structure of legitimation strategies beyond the more simple 'local vs. non-local exchanges that were identified for the knowledge dimension. Also the export of legitimacy can be further differentiated into activities targeting other national/regional-scale institutional contexts and activities targeting the 'global' regime.

2.3 Analytical framework

On this basis, we propose a typology of path creation constellations, which is based on two analytical dimensions (see Tab.1). The first dimension describes the strength of related knowledge and capabilities a region can rely on. The second dimension depicts the resistance of the established regime against a newly emerging industry. The strengths of this resistance can be measured by two conditions: a) the number of alternative regimes currently prevailing in a sector and b) the degree by which the current regime is challenged by emerging alternative industries and /or external conditions. The dominance of the current regime, can be measured as a gradient between highly dominant and highly polycentric constellations (van Welie et al., 2018). A highly dominant, monolithic regime structure, can be found in the electricity sector, which is strongly dominated by centralized generation, long distance transport, large utility companies and decentralized consumption (Verbong and Loorbach, 2012). A polycentric structure can be found for instance in the transport sector where several alternatives co-exist to provide people with mobility services (cars, buses, bikes, etc.) (Geels et al., 2011). The second condition can be measured by how strongly the existing regime is challenged by different societal needs or institutional logics. In terms of transitions thinking, this relates to the fit

Tab. 1 Path creation constellations in emerging industries.

		Institutionalization/ coherence of socio-technical regime	
		weak	strong
Availability of Knowledge and capabilities	high	lead market	export-driven
	low	challenge-driven	regime lock-in

between pressures from the "socio-technical landscape" and whether the prevailing socio-technical regime is considered as being able to respond to these pressures.

Based on these conceptualization, we may now identify different constellations of knowledge and legitimacy, which can be leveraged for regional path creation. In general, we would expect that the more related knowledge a region provides, the higher its ability to create a new path in the emerging industry. In terms of institutional contexts, we would expect that the stronger and the more unchallenged an existing regime is, the more difficult it will be to establish a new path in the region (Boschma et al., 2017). These two structural conditions result in four ideal type regional path creation constellations.

A first constellation concerns those regions, which host high levels of related knowledge and relatively weak regime structures. This situation can be characterized as a *lead-market constellation*. With easy access to relevant knowledge and a conducive institutional environment, local firms may find it easy to lobby for supportive policies, to install local niche markets and to find competent partners for raising financial resources. The resulting path creation dynamics would then likely start with local niche formation for new socio-technical configurations, the endogenous build-up of supportive innovation systems, and slowly result in the establishment of alternative regime structures. Once this is achieved locally, export of ready-made solutions may be endeavoured, and local actors may seek to alter the global regime through targeted institutional work in other regions and at the global-scale.

A second constellation depicts regions that possess related knowledge capabilities but face strong path-dependencies from the incumbent regime. The proponents of the emerging industries may therefore be forced to gain legitimacy in foreign markets. Successful penetration of foreign markets may subsequently be used to mobilize resources domestically. The related path creation dynamics may be strongly dominated by transnational companies who can potentially build up markets for technologies, which do not rely on short distance exchange

between market formation and technology development, all over the world. Hence, this constellation can be labelled as *export-driven*.

A third constellation relates to regions, which lack competitive stocks of related knowledge, while also facing rather weak path dependencies from existing regimes. The latter may be due to a lack of provision with certain services (such as those found in informal settlements) or strong landscape pressures for which the novel technology would provide a better solution (e.g. arid areas having to fight with severe water shortages). These regions will depend on external actors providing and promoting alternative solutions, building up corresponding markets, or helping to build up a stronger knowledge base through cooperation with external companies, FDI and/or inward labour mobility. We call this a *challenge driven constellation*.

Finally, regions which lack knowledge and capabilities and face strong path dependencies through (global) regime structures may be characterized as a *regime lock-in constellation*. This is arguably the most challenging constellation, since regional actors would have to attract or absorb both legitimacy and knowledge from elsewhere in the local path creation process. Although instances of successful path creation have been described for such situations (i.e. the example of on-site water reuse in Beijing or of PV panel manufacturing in China), any strategy in this situation will likely face strong barriers.

While the typology in Tab. 1 depicts ideal-type path creation constellations, the actual strategies of regional policy makers or local companies may still leverage the full portfolio of endogenous and external knowledge and legitimacy mobilization patterns as identified in section 2.3. I.e. we would expect actors in a lead market and export-driven constellation to be able to engage in the export of legitimacy to other regions and at the global-scale. Attraction and absorption of legitimacy may in turn matter in all types of configurations, to either create novel (export-driven, regime lock-in) or maintain existing (challenge-driven, lead-market) institutional environments. Whether or not the potentials of a given constellation will be leveraged, or even

what kind of strategies the individual actors will mobilize to overcome resource deficits, remains an empirical question. We will in the following operationalize this generic framework, and map the diversity of resource mobilization strategies for an illustrative empirical case.

3. Mapping global legitimation activities for modular water technologies

To illustrate and validate our framework empirically, we will apply it to the case of modular water technologies, which represent a currently emerging, radically novel industrial path in the water sector. The global water sector had an estimated investment volume of over 500 billion US Dollar in 2014, which is only a fourth of the yearly investments needed to fulfil the sustainable development goals by 2030 (OECD, 2018, Hutton and Varughese, 2016, Winpenny, 2015). It is dominated by publicly or privately managed water utilities, which often collaborate with large multinational equipment suppliers, engineering consultants and service providers like Dow, Veolia, Suez or Thames Water (Lieberherr and Fuenfschilling, 2016) . Next to public funding, investment in large-scale water infrastructures and technologies increasingly comes from private investors, but also multi- and bi-lateral development banks and agencies (OECD, 2019).

At the same time, the sector is increasingly confronted with grand challenges like climate change and fast urbanisation which render the operation and maintenance of large-scale infrastructures increasingly difficult (Sadoff et al., 2015, UN-WWAP, 2015, Eggimann et al., 2018, OECD, 2019). Small, flexible, modular water technologies are hence increasingly considered as a promising means to flexibly alleviate water scarcity, support cities in becoming more water sensitive and resilient, and helping them to implement more sustainable urban water management practices (Larsen et al., 2016, Wong and Brown, 2009). Often applied in small-scale, off-grid contexts, modular water technologies can benefit from so-called “economies of

unit numbers", granting them management and cost advantages compared to conventional large-scale water infrastructures (Wilson et al., 2020, Dahlgren et al., 2013).

Given these characteristics, they fundamentally challenge the dominant regime logic in the water sector, which predisposes that technologies should be designed for large unit-scale and custom-built water infrastructures (Fuenfschilling and Binz, 2018). In contrast to this highly institutionalized regime, the actor network pushing for modular technologies is still in a rather nascent stage, with limited commercial applications and an actor structure, which is dominated by small and medium sized enterprises (OECD, 2019). Funding still mostly originates from grants provided by private foundations and venture philanthropy, like through the Bill and Melinda Gates Foundation (BMGF), but also NGOs, development agencies and some social impact investors (ibid.).

In light of these specifications, we expect strong legitimation challenges for actors pioneering innovative modular approaches and for regime actors defending the centralized paradigm. We furthermore expect a broad range of multi-scalar legitimation activities as the centralized socio-technical regime of the urban water sector is globally rather standardized with relatively little regional variations (Fuenfschilling and Binz 2018).

3.1 Measuring legitimation and discursive path dependency

To operationalize our framework, we constructed a dataset by means of a semi-qualitative methodology, we call socio-technical network analysis (STNA), which rests on a discourse and social network analysis tool (Discourse Network Analysis) developed in the political sciences (annonymized, submitted, Leifeld, 2017, Leifeld, 2013). Given the global ambition of this study, we do not aim to analyze legitimation through a full-fledged discourse analysis (e.g. Geels and Verhees, 2011), but rather focus on organizations' (positive or negative) evaluations of technologies or related infrastructural and institutional elements in media coverage. I.e. newspaper articles are coded for individual statements through which organizations contribute

to a specific conducive or obstructive narrative (narrative events in the remainder) around certain technologies or institutions. STNA is a useful tool for such an analysis, since it reduces narrative events – be it statements around institutional or technological elements– to an interaction between *actors* that make normative claims about certain *concepts*. The time-referenced, coded data that is retrieved here based on qualitative content analysis from extensive newspaper databases, is subsequently transformed into network matrixes, which enable the quantification of various relationships between actors and concepts across time, allowing for the analysis of the alignment and reconfiguration processes associated with changing socio-technical regimes (Heiberg et al., 2020).

In distinction to the temporal focus of the method, we here investigate the geographical patterns behind the coded discursive events. We thus capture contributions to legitimizing and de-legitimizing narratives made by niche and regime actors around technologies, types of infrastructure or policies/institutions in the media. For this, we use a binary qualifier variable to denote the contribution to an either legitimizing or de-legitimizing narrative. This distinction, of course, constitutes a strong simplification of reality. Different narrative events may contribute to varying degrees to legitimation (or de-legitimation) of specific technologies. However, considering the fundamentally opposing infrastructure logics associated with conventional and modular water technologies, it was usually easy to identify whether an actor framed them in a conducive or obstructive way.

Further, a valid operationalisation of our framework requires the identification of the spatiality and scalarity of the narratives contributions identified in the articles. To this end, we coded three types of spatial variables associated with each narrative event. First, actors – mostly organisations in our case – are assigned to a specific location where they carry out most of their activities (from now on termed as *actor location*). Here, we roughly distinguished between the national or global contexts, which refers to the dominant scale where activities take place.

Global-scale organisations (such as TNCs, NGOs, industry associations, etc.) are defined by being active in various locations around the world. If necessary, and not enclosed by our textual sources, the assignment to scales is based on supplementary desk research.

Second, we identify whether the narrative an organisation contributed to includes a spatial reference to a specific case or activity somewhere abroad (*narrative location*). Typical examples involve the reference to companies or global NGOs that promote specific technologies abroad, or the reporting of success or failure of specific projects form another geographical contexts. For instance, in Israeli newspapers, a recurrent narrative promoting the local modular industry hinted at a huge market for these technologies emerging in China, and made a reference to Israeli companies' successful involvement in experimental projects in several Chinese regions. For such narratives, we would code China as the 'narrative location'.

The third locational variable denotes the geographical places and scales of the audience articles are targeting (*audience location*). This assumes that a media article always wants to inform some geographically specified readership. The audiences addressed are either dominantly (sub-)national-scale public audiences, e.g. for nationally or regionally distributed outlets like the Times of India, The Guardian, or the Washington Post, or global-scale expert audiences, as in sector-based global magazines like Chemical Week or Business Monitor Online. In national legitimation processes, media articles capture the interplay of different value perspectives in policy contexts within clearly delimited territorial boundaries. Global-scale outlets instead capture the (dis-)agreements among global experts with academic, business or financial backgrounds.

As will be elaborated in chapter 3.3, capturing these three variables will allow us to build indicators that measure endogenous legitimation, attraction, absorption and export at the national-scale for several country cases.

3.2 Data sources

To compare different countries' path creation constellations, we select indicators for both the availability of place-based knowledge and capabilities around water technologies and for the strength of the socio-technical regime around centralized water infrastructures in a country. While an analysis at the regional level would be possible, due to the lack of density and structure of our global dataset the level of spatial aggregation in this study is the country level. For the identification of existing local knowledge and capabilities, we access innovation performance indicators from the OECD.stat database, which are based on PATSTAT data on patent family filings that were filtered for water technologies (see. App. 1)[1] [2] . To assess the regime strength dimension, we collect centralized sewerage connection rates from the WHO/Unicef Joint Monitoring Project (JMP) on water supply, sanitation and hygiene and combine them with the measure of discursive path dependency in media, built from our own dataset (see 3.1). To identify legitimation activities globally, over 180 English-speaking newspapers covering most OECD countries plus India, South Africa, China and Singapore as well as selected global expert magazines were accessed through the online newspaper repository LexisNexis. The outlets were filtered for articles dealing with solutions to solve water problems during 2011-2018 (see App. 2 for the technological specification of modular versus centralized systems). The source base was built around the "Major World Publications" assemblage that contained a selection of the world's major English-speaking newspapers, industry magazines and trade publications, which "are held in high esteem for their content reliability" (LexisNexis, 2018)[3]. The base was further manually extended for media coverage in regions like India and Africa that were only

[1] We use patent data as in indicator to compare the creation of knowledge and capabilities across countries due its availability over long time-spans and comparability, especially at the country level (Archibugi & Planta, 1996). While we are aware that not all innovations in the water sector may be patented, previous investigations of innovation activities in the water sector have shown its general applicability for the sector (e.g. Moro et al 2018; OECD, 2019)

[2] Note that the Appendix is available online only

[3] The LexisNexis Academic database has been updated in spring 2019. Its successor LexisUni does not provide source assemblages like "Major World Newspapers", nor background information on the reach of individual newspapers anymore.

sparsely or not at all represented by the initial assemblage. We only included outlets that were covered over the whole time period and that were considered of national or international importance by LexisNexis (see App. 3 for a full list).

A search query was then formulated (App. 4) to filter articles published between 2011 and 2018 from the source base. Of initially about 800 articles, 563 where deemed relevant and subsequently coded by a single coder with help of DNA-software (Leifeld, 2018). The first author developed and tested a coding scheme (for details on the coding scheme see Heiberg et al. 2020) before a second coder was educated in consistently applying it through several coding runs with test data involving feedback rounds and inter-coder reliability checks.

3.3 Indicators for discursive regime strength and multi-scalar legitimation processes

The narrative events captured from our databse enable us to disentangle the endogenous and multi-scalar dimensions of legitimation that we have concepualized in section 2. To get an initial idea of the regime strength in different countries and to limit our dataset to the most prevalent country cases, we identify the geographical hot spots of legitimation activities. This is achieved by mapping the frequencies of narrative events at the level of national audiences.

For each country case, the absolute numbers of legitimizing and de-legitimizing narrative events per year are subsequently taken to construct a **conducive narrative share** (Fig. 2, I). It is defined by the sum of narrative events that legitimize modular technologies or de-legitimize conventional technologies divided by the sum of all narrative events used in a specific country. The higher the measure, the more challenged is the regime in discursive terms. Together with the connection rate to centralized water infrastructures, this indicator measures the degree of institutionalization of the conventional socio-technical regime in a given country.

We then ask how prevalent processes of endogenous legitimation, absorption, attraction, and export of legitimacy are in select hotspot countries. This enables us to assess the importance of multi-scalar legitimation processes in countries with differing path development constellations.

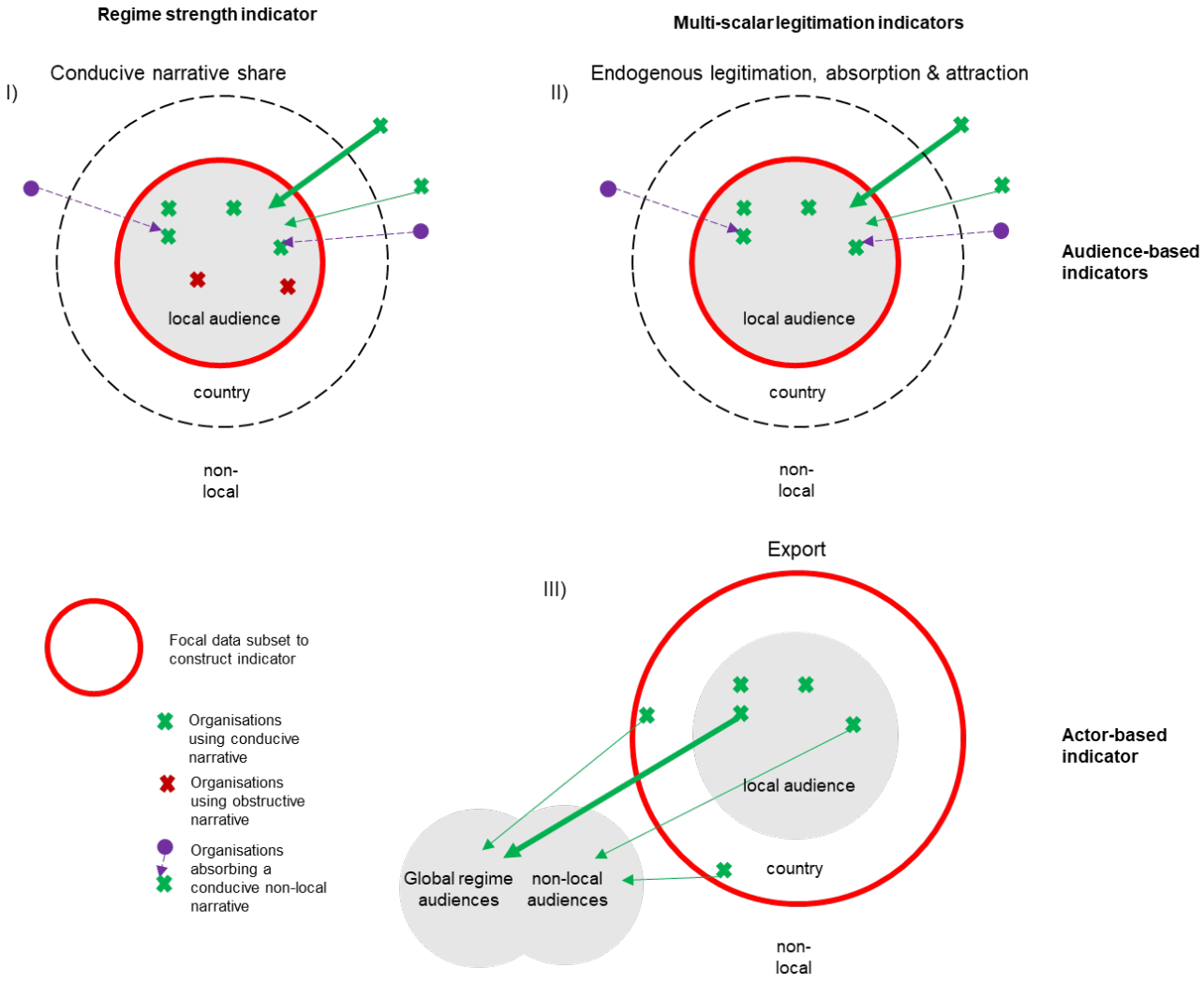


Fig. 2 Data subsets to calculate indicators for regime strength and multi-scalar legitimation **processes. Own figure**

For assessing the prevalence of *multi-scalar* legitimation processes, we develop four indicators.[4] The relative importance of endogenous legitimation inside a country is given by the **endogenous legitimation** indicator (Fig. 2, II). It measures the share of conducive narrative events by local actors among all conducive narrative events in a country. The importance of attraction processes is captured by the **attraction** indicator (Fig. 2, II). It is given by the share

[4] For a detailed description of each indicator and its calculations see App. 5

of conducive narrative events by non-local organisations among all conducive narrative events in a country. Finally, the **absorption** indicator (Fig. 2, II) represents the share of narrative events that absorb success stories from elsewhere among all conducive narrative events in a country. Unlike attraction, absorption is operationalized as purely transnational processes because success or failure cases that can be absorbed for legitimation purposes are necessarily associated with stories from distinct other countries or regions.

While endogenous legitimation, import and absorption can be calculated based on narrative events addressing an audience in a specific country (*audience-based*), the **export** indicator follows a slightly different logic since it is calculated by the share of conducive narrative events by local actors addressing the global-scale or another countries' audience (Fig. 2, III). The export indicator is hence *actor-based*. Fig. 2 illustrates the logic behind the different indicators and their respective data subsets.

Mapping the path development constellations across countries based on their respective knowledge capabilities and regime strength allows us to put the multi-scalar legitimation processes deployed in these countries into perspective.

4. Results

The main descriptive statistics can be obtained from Tab. 2. Roughly 2/3 of all the captured narrative events legitimize the existing regime and conventional technologies. The remaining third of events are conducive to modular technologies. We capture data from 6 countries (the rest of the world being clustered in larger world regions) plus the global-scale regime audiences (adding up to 16 audience locations). Most narrative events can be identified in India, the USA, Singapore, South Africa, the UK and in Israel, as well as at the global scale. Narrative events addressing these major national and global-scale audiences account for over 78% of all

Tab. 2 Dataset

Years observed:	8
Documents:	576
Narrative events after duplicates/document cleared:	1435
Narrative events conducive to conventional technologies	911
Narrative events conducive to modular technologies	524

DNA Variables:	
Organisations:	566
Organisation types:	8
Concept codes (referred to in narratives):	51
Actor locations:	20
Narrative locations:	19
Audience locations:	16

Overall framings per country (or clustered in supra-national regions):	count	% of subtotal
India	280	21.93
USA	199	15.58
Singapore	150	11.75
South Africa	138	10.81
UK	104	8.14
Israel	96	7.52
East Africa	66	5.17
East Asia	53	4.15
Southern Africa	50	3.92
Oceania	45	3.52
Canada	41	3.21
Europe	30	2.35
Central and West Africa	14	1.10
Other Africa	6	0.47
China	5	0.39
subtotal	1277	100.00
% of subtotal (top-6 countries)	967	75.72

Overall narrative events in global-scale expert discourse:	count	% of total
Global-scale	158	11.01
% of Global-scale and top-5 countries		78.40
Total	1435	100.00

legitimation activities in the dataset (Tab.2). We will position these six most prevalent countries in our typology of path creation 'constellations' and then analyse their multi-scalar legitimation processes.

4.1 Path creation constellations

We will start the discussion of our empirical results by assigning the six countries to different quadrants of our analytical framework based on their pre-existing knowledge capabilities and regime strength (Tab. 3).

Tab. 3 Country level indicators for path creation constellations

Availability of knowledge & capabilities

Knowledge indicators

	Average annual water technology patent family filings 2011-2016, per 1 Mio inhabitants*	Share of water-related patents among all patents
India	0.08	1.30
USA	7.93	1.44
Singapore	11.10	2.45
South Africa	0.30	3.31
UK	4.02	1.85
Israel	9.54	1.50
OECD	7.22	1.70

* PATSTAT data from OECD.stat

Regime strength

Infrastructural indicators

Sanitation service levels 2017, % of households*

	sewered	non-sewered
India	11	89
USA	82	18
Singapore	100	0
South Africa	58	41
UK	97	3
Israel	99	1

* WHO & Unicef data from Joint Monitoring Project on water supply, sanitation and hygiene

Discursive indicators

Narrative events concerning modular water technologies 2011-2018*

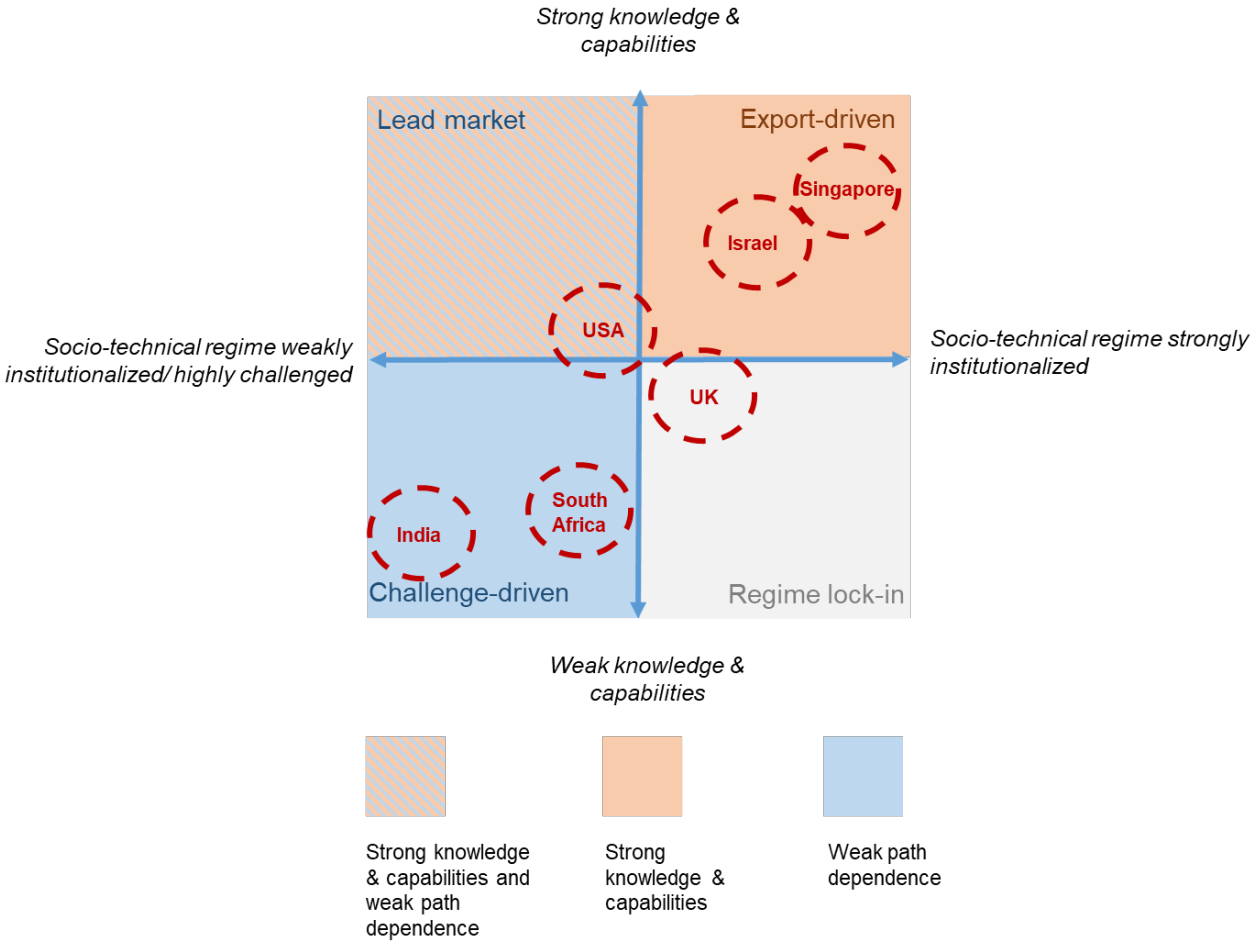
	All narrative events	Conducive narrative events	Conducive narrative share %
India	280	138	49
USA	199	68	34
Singapore	150	20	13
South Africa	138	41	30
UK	104	49	47
Israel	96	40	42

*Own database

The analysis (visualized in Fig. 3) shows that in India, a higher conducive narrative share for modular technologies coincides with a weak regime in centralized infrastructures. Combined with low knowledge and capabilities, this reflects a challenge-driven path creation constellation. In Singapore, in contrast, high patenting in water technologies and a 100-percent connection rate to centralized infrastructures go hand-in-hand with a strong regime orientation,

thus indicating an export-driven constellation. Israel, South Africa and the US deviate from these clear patterns showing a moderate conducive narrative share but clear differences in terms of built infrastructures and patenting activities. Israel, a leading innovator in the water field, combines strong patenting with a moderately strong conducive narrative share and a complete lock-in in centralized infrastructures, thus resulting in an export-driven constellation. South Africa, a laggard innovator, in turn, has a very weakly established centralized infrastructure regime, resulting in a more challenge-driven constellation. The US constitute an intermediate case with moderately developed patenting activities and a 20 percent share of non-sewered infrastructures, thus representing a potential lead-market constellation. Finally, the UK constitutes a case with weak to moderate patenting activities, a strongly dominant centralized infrastructure regime, which is however highly challenged by multiple narratives promoted in public media. Taken together, this results in a regime lock-in constellation.

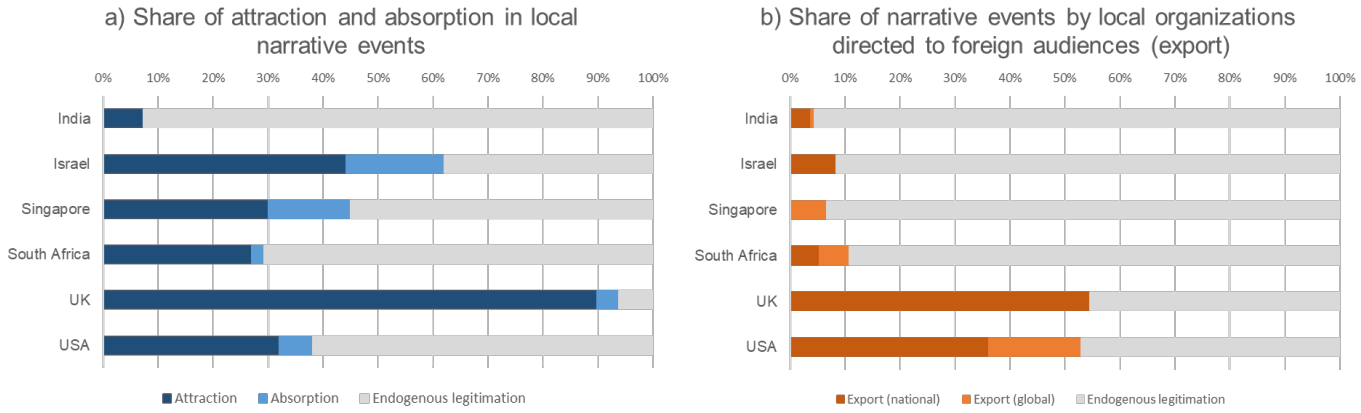
Fig. 3 Path creation constellations across countries. Own figure.



4.2 Multi-scalar legitimation processes

In what follows, we will review the indicators for multi-scalar legitimation processes introduced in section 3.3 to assess their importance in each of the four quadrants of our typology. This enables the assessment of whether certain multi-scalar legitimation processes may be more relevant in certain quadrants than in others. The values of the audience-based attraction, absorption and endogenous legitimation indicators can be obtained from fig. 4a. The different scores will be contextualized with additional qualitative information drawn from the text analysis.

Fig. 4 Multi-scalar legitimation processes across countries. Own figure.



Lead market constellation (USA)

The USA constitute the only country in our dataset, whose pre-existing knowledge capabilities and regime strength allows it to embark on a lead-market strategy. For countries in this quadrant with a strong knowledge base and challenged regime structures, we would not only expect the creation of a conducive environment locally, but also strong export potential of legitimacy both to other countries and to the global regime. As emerges clearly from fig. 4, US actors, indeed, engage more strongly in the export of conducive narratives than actors from most other countries featured in our dataset. The respective US actors involve tech firms in the modular technology field, such as Cambrian Innovation or RWL Water, as well as NGOs, industry associations and several public authorities (especially in arid western states like California or

Arizona). Most strikingly, over 16% of all conducive narratives by US actors are associated with statements addressing global-scale audiences. Most of these export activities are associated with statements by big universities such as MIT, Caltech and Harvard, as well as individual venture capital firms directed towards international industry and policy audiences. Hence, diverse US actors seem to exhibit the ability to contribute to dominant narratives among global professionals in the water sector. Directly shaping the prevalent global regime narratives may be a powerful method for big countries, like the US, to positon itself as global lead-market, since the professional community will disseminate and reproduce these narratives in other parts of the world and hence legitimize the US solutions there. At the same time, professional global networks may also feed legitimacy back into the US and hence strengthen the emerging niche in the long run.

Further, the US media coverage is also strongly influenced by attraction and absorption processes, which make up about 40% of all conducive narrative events in the country. Actors legitimizing modular technologies in the US are composed by international organizations (like the WHO), but also Tech-firms from Israel (like IDE), or Australia (Aquacell), that see a potential market for modular technologies in the US. The latter indeed has recently become a key provider of on-site water reuse technologies in Northern California. Further, international universities are frequently voiced in the US media (e.g from Germany, Israel and the UK). Absorption in fact relates to the reporting of successful application cases from all other countries investigated in this paper, including the BMGF activities in Durban (South Africa) but also cases from Israel, Singapore, India or Australia are often used by University and NGOs advocating modular technologies.

In addition, the text analysis revealed that the US faced particular regional environmental pressures, e.g. through droughts that hit California and the Western states peaking between 2014 and 2016 (NIDIS, 2018). These events repeatedly pushed water issues into public media, which additionally attracted global and transnational experts to legitimize modular solutions

locally. Overall, the US context can thus be characterized by strong export of legitimizing narratives to the global regime, as well as a balanced mix of attraction, absorption and endogenous legitimation activities creating a supportive institutional environment domestically. Combined with its promising knowledge stocks, the US strategy benefits from an active engagement in multi-scalar legitimation processes to further develop and advance its lead market trajectory in the modular technology industry, and therefore might become a forerunner of a sectoral transition.

Export-driven constellations (Israel, Singapore)

For countries with strong local knowledge capabilities, but also strong regime structures, we expect analytically distinct legitimation strategies, which depend more on export activities with the subsequent absorption of success stories into the local context. As discussed above, Israel and Singapore can be positioned in this quadrant. Israeli actors conducted about 10% of their narrative events in export (Fig. 5, III). Unlike in the US case, they do not target the global regime but attempt to directly support export markets in other countries, most prominently in the US. At the same time, also absorption processes play a comparatively strong role in that case. Most of the absorbed narratives are built around Israeli companies' (such as Emefcy) successful engagement with modular water technologies in foreign markets, for example in China or the Americas. Additionally, Israel manages to attract European, US and global-scale organizations to co-legitimize the emerging industrial path around modular water technologies in Israeli media outlets. Overall, multi-scalar legitimation processes make up the largest part of all legitimation activities in that case. Fulfilling its potential in an export driven constellation (e.g. targeting markets like the USA), path creation in Israel heavily benefits from multi-scalar legitimation, partly compensating for the lack of an existing domestic market.

Singapore is characterized by a similarly strong deployment of attraction and absorption processes among all conducive narrative events. Unlike Israel, however, the discourse in

Singapore remains strongly dominated by narratives around conventional large-scale water technologies (Fig. 5, II). Also, unlike Israel, Singaporean promoters of modular technologies rather target the global regime and not specific other countries. An explanation for this pattern may be found in Singapore's strong export orientation in centralized wastewater reuse and desalination, which builds on its 'Four National Taps' water strategy(PUB, 2018). Since the national water technology export activities are already strongly focussed on this trajectory, modular technology proponents face strong opposition by export-oriented competitors and rather follow a long-term strategy in changing the global socio-technical regime. While Israel thus follows a rather classic export-driven legitimation strategy including export and absorption from and to other countries, in Singapore, the regime resistance cannot be overcome yet, and actors thus rather focus on legitimizing niches at the global-scale. Overall, the data from Israel and Singapore suggests that the success of an export-driven path creation constellation not only depends on its structural preconditions but also on its effectiveness in mobilising non-local legitimacy.

Challenge-driven constellation (India, South Africa)

Countries that largely lack knowledge and capabilities but at the same time represent potentially conducive institutional environments due to strong challenges to the regime, may in turn be provide an attractive environment for foreign legitimizers and hence depend more heavily on attraction processes next to endogenous legitimation. In our dataset, India and South Africa exemplify this path creation constellation. Legitimation patterns within both countries are strongly dominated by endogenous legitimation and to a lesser extent by attraction. Export to other countries and the global regime remain low, and absorption from other countries is virtually inexistent.

South African actors appear to influence the global regime in few instances but much less strongly than US or Singaporean actors. Where it occurs, it is driven by the University of

KwaZulu Natal and Durban municipality, who are also the most prominent proponents domestically, having a long standing record on experimenting with and implementing modular technologies in informal settlements (Sutherland et al., 2015). Apart from these, we also find the government promoting modular solutions in response to severe droughts in 2015/16 (Baudoin et al., 2017). These pressures also attracted international organizations like the International Water Association (IWA) and the UN to legitimize modular solutions in South Africa. Further, the qualitative data suggests that modular water technologies are already an institutionalized part of many Indian and South African cities, since decentralized and modular sanitation is a widely diffused practice in both countries (Ulrich et al., 2018, Schellenberg et al., 2020).

This notwithstanding, India qualitatively differs from South Africa in having a long history in the application modular water infrastructures. Narratives by Indian actors thus often revolve around these pre-existing modular water infrastructures, which are promoted by a large variety of actors ranging from public authorities to NGOs and companies. Regional discursive hubs can be identified in particular in the southern states of Tamil Nadu, Karnataka and Maharashtra, as well as some Northern States, such as Uttar Pradesh and Himachal Pradesh. In these regions, often, local environmental problems, like overly polluted rivers and sewerage overflow lead organizations to suggest an increased use of modular technologies for greywater reuse, rainwater harvesting or on-site wastewater treatment. Overall, we may expect challenge-driven countries to be able to create legitimacy endogenously building on existing institutional templates, and external landscape pressures. While institutional environments already provide a window of opportunity for path development in such cases, the lack of knowledge capabilities may require the absorption and attraction of knowledge from beyond the region. A feasible strategy in this constellation would thus involve the attraction of capable foreign firms and experts based on the strategic promotion of local markets and legitimation trajectories.

Regime lock-in constellation (UK)

Regime lock-in constellations, finally, are the hardest to tackle even with multi-scalar legitimation processes, since the proponents of alternative solutions are confronted with weak knowledge capabilities and strongly centralized regime structures. To create a domestic path, they may thus have to engage in a diversity of legitimation strategies in parallel, such as developing an export-driven trajectory (similar to the Israeli case), while also attracting foreign firms to both transplant external knowledge and discursively challenge the domestic regime. The UK constitutes an illustrative case in this regard, since almost all legitimation activities in domestic media coverage are based on attraction processes. This has two reasons. On one hand, there have been frequent reports around the Californian drought between 2014-2016, especially in the Guardian, giving a voice to US entrepreneurs in the UK's small, modular technology field. On the other hand, the BMGF, who is funding various British research partners in the context of their 'reinvent the toilet challenge', is frequently pushing their ideas in British media.

Thus, while British infrastructures and endogenous legitimation is strongly focussed around the centralized regime, British media provides a platform for external industry proponents to promote their ideas around modular water technologies, effectively challenging the socio-technical regime. International actors, like BMGF, may find the UK an attractive location to legitimize modular technologies, in order to gain attention from investor based in London or powerful British companies. At the same time, British industry proponents themselves are mostly targeting foreign markets in the rest of the English speaking world, but not the global regime. Hence, for the UK, we may observe a combined strategy of attracting foreign legitimizers to the otherwise strongly path dependent institutional environment, and British industry proponents seeking their luck in export-markets. The British case thus illustrates how an internationally well-connected country, despite facing a regime lock-in constellation, may

become a hub for transnational legitimation flows and even generate opportunities for path creation thanks to the attraction of foreign legitimizers.

5. Discussion & conclusions

The goal of the present paper was to provide a conceptual and empirical inroad to disentangle multi-scalar legitimation processes in the context of emerging industries. We have demonstrated how regional path creation constellations differ according to their existing knowledge and capabilities, and the institutionalization of the socio-technical regime relative to the emerging industry. We have then shown how within these varying structural constellations multi-scalar legitimation processes can be empirically identified through the appearance of narrative events in media. In light of the presented findings, our research brings to the fore several aspects that may enrich work on non-local sources of industrial path creation in EEG and beyond.

While recent research on path creation has focused mostly on regional and national institutional dynamics (Gong and Hassink, 2019, Miörner and Trippl, 2018), our work is innovative in proposing a multi-scalar perspective on institutional dynamics. Our results suggest that multi-scalar legitimation processes may shape a region's ability to create industrial paths in emerging industries. In particular, we illustrated the importance of non-local sources of legitimacy for regional path creation, parallel to non-local sources of knowledge (Trippl et al., 2017). Our results indicate that an explicit consideration of multi-scalar flows of legitimacy is crucial for identifying potential strategies of regional actors. Integrating these insights with recent understandings of multi-scalar knowledge flows, we may formulate a number of original hypotheses for success conditions of path creation processes. Tab. 4 illustrates how different

types of multi-scalar knowledge formation and legitimation processes may matter across different path creation constellations.

Tab. 4 Relevance of multi-scalar ressource formation strategies in different path creation constellations. Own figure.

		Lead market	Export-driven	Challenge - driven	Regime lock-in
Knowledge	Endogenous	++		-	
	Attraction & Absorption	+		++	
	Export	++		-	
Legitimacy	Endogenous	++	-	++	-
	Attraction	+	+	+	++
	Absorption	+	++	-	++
	Export	++	++	-	-

++ high relevance
\+ intermediate relevance
\- lower relevance

In a lead-market constellation, knowledge and legitimacy can be developed endogenously. Actors in a lead market constellation will thus likely engage in the export of both knowledge and legitimacy in order to shape supportive institutional environments both in the global regime, as well as in other regions. Lead market countries like the US, may addtionally benefit from non-local sources of legitimacy in a similar manner as organizationally thick and diversified regions benefit from absorptive capacity and attractiveness in the anchoring extra-regional knowledge resources (Trippl et al., 2017). In an export-driven constellation, like Israel, knowledge generation may follow a similar pattern, but the lack of a conducive domestic institutional environment needs to be compensated by active export, absorption, as well as attraction of legitimacy, which can be facilitated through existing knowledge and experimentation collaborations abroad. If these multi-scalar legitimation strategies fail, export-driven constellations may reflect organizationally thick and diversified regions that fail to create a novel path, mostly due to their strong local institutionalization of the socio-technical regime.

Put differently, in an export-driven constellation, multi-scalar legitimation processes serve to mobilise a path potential that could otherwise not be created or maintained (see also Kwak and Yoon, 2020).

A challenge-driven constellation like India, in turn, has ample domestic drivers for building up legitimacy endogenously, and benefits particularly from knowledge and other missing system resources attracted from abroad. Their situation may best compare to an organizationally thin, or peripheral region, in which actors face the strongest difficulties but can also reap of the largest benefits from absorbing extra-regional knowledge and other resources (Trippl et al., 2017). Finally, in a regime lock-in constellation, resources need to be drawn from non-local sources or be developed from scratch domestically. Since the latter often proves difficult, actors in a regime lock-in constellation may chose a legitimation strategy that builds strongly on extra-regional legitimacy. To some extent, a regime lock-in constellation may relate to old industrial regions, for which empirical studies have suggested that multi-scalar institutional interventions may matter just as much as the absorption of non-local knowledge (Dawley, 2014, Dawley et al., 2015, Trippl et al., 2017, Hassink et al., 2019).

Along these hypotheses, our results point to the importance of interactions between regional entities and global socio-technical regime structures (Fuenfschilling and Binz, 2018) that may substantially affect the path creation prospects of a region. Beyond only looking at institutional environments *at* different spatial scales, mostly referring to regulation and policy processes (Martin, 2010, MacKinnon et al., 2019), we have shown that these institutional environments may be affected by processes that run *across* different spatial scales. The transnational absorption of legitimacy through narratives around foreign success cases, or even multi-scalar processes, like the attraction and export of legitimacy from and to a global-scale community of experts that reproduces the global socio-technical regime, reveal that new windows of opportunity for paths in emerging industries may shape up where theory would otherwise not have suggested (as the cases of Israel, or the UK illustrate). Hence, only looking at endogenous

institutional work for an emerging industry, or at static layers of institutions that affect path creation regionally, misses the diverse ways through which industry proponents may influence institutional environments in and across different spatial scales.

We started this paper with the ambition to analyze the importance of multi-scalar institutional dynamics for regional industrial path creation. However, our actual framework has focused on legitimation processes. A more encompassing perspective would additional have to consider other relevant system resource formation processes, such as market formation and the mobilization of financial investment (Binz et al. 2017). Also, the proposed method could be further improved. Since we only capture legitimacy generated through articles in selected media outlets, we cannot make any claims about legitimacy conveyed through more tangible actions, such as investment decisions, or presentations at trade fairs or conferences (Bork et al., 2015). Future research should thus venture into the identification of broader valuation concerns, which may require the triangulation of data generated by means of a variety of methods.

Also our method could be applied for analyses at the national or regional level to gain more in-depth insights into the sub-national validity and specificity of the processes, we have studied in this paper. Eventually, an analysis of the role of multi-scalar legitimation processes in more traditional and established sectors could provide important insights beyond our more narrow focus on emerging industries. However, we maintain that by addressing the problem of multi-scalar legitimation processes in emerging industries through media, we provided an important inroad to understanding the systemic interplay between novel technologies, institutions and knowledge in a globalizing innovation and industry formation race. Contextualizing the contribution of this paper in this wider conceptual perspective furthermore enables to spell out productive trading zones with related disciplinary theorizing such as neo-institutional sociology or the literatures on institutional work and entrepreneurship. Embracing these theoretical insights is a topical frontier for geographers and transition scholars alike, particular in light of

increased efforts to understand path development in emerging, or green industries (Trippl et al., 2020).

App. 13.000 words (incl. references)

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Appendix

App.1: Search strategy for patent data OECD.stat

The search is built on an adjusted selection of environment-related water technologies (ENV-tech) based on OECD (2009), Martinez (2010), Haščič and Migotto (2015), Haščič et al. (2015) Leflaive et al. (2020) for the identification of technology development based on simple patent families (patent applications protecting the same priority) which can be traced back to individual inventors from individual countries. Since modular technologies cannot be defined easily within the realm of individual patent classes, we assume for reasons of simplicity, that existing knowledge and capabilities in environment-related water technologies reflect the availability for innovative capabilities in the modular technology field.

	Description
	1.2 Water pollution abatement
IPC class	**1.2.1. Water and wastewater treatment**
B63J4	Arrangements of installations for treating waste-water or sewage
C02F	Treatment of water, waste water, sewage or sludge
C09K3/32	Chemistry; Materials for treating liquid pollutants, e.g. oil, gasoline, fat
E03C1/12	Plumbing installations for waste water
E03F	Sewers –Cesspools
IPC class	**1.2.2. Fertilizers from wastewater**
C05F7	Fertilisers from waste water, sewage sludge, sea slime, ooze or similar masses
IPC class	**1.2.3. Oil spill clean-up**
E02B15/04-10	Devices for cleaning or keeping clear the surface of open water from oil or like floating materials by separating or removing these materials
B63B35/32	Vessels or like floating structures adapted for special purposes - for collecting pollution from open water
C09K 3/32	Materials for treating liquid pollutants, e.g. oil, gasoline or fat
	2.1 Demand-side technologies (water conservation)
IPC class	**2.1.1. Indoor water conservation**
	Faucets and showers
F16K21/06-12	Self-closing valves, i.e. closing automatically after operation, in which the closing movement, either retarded or not, starts immediately after opening
F16K 21/16-20	Self-closing valves, i.e. closing automatically after operation, closing after a predetermined quantity of fluid has been delivered
	Aeration of water
F16L 55/07	Arrangement or mounting of devices, e.g. valves, for venting oraerating or draining
F16K 21/16-20	Jet regulators with aerating means

	Sanitation (dual-flush toilets, dry toilets, closed-circuit toilets)
E03D 3/12	Flushing devices discharging variable quantities of water
E03D 1/14	Cisterns discharging variable quantities of water
A47K 11/12	Urinals without flushing
A47K 11/02	Dry closets
E03D13/007	Waterless or low-flush urinals
E03D5/016	Special constructions of flushing devices with recirculation of bowl-cleaning fluid
	Greywater
E03B1/041	Greywater supply systems
	Home appliances
Y02B 40/46	Optimisation of water quantity (for dishwashers)
Y02B 40/56	Optimisation of water quantity(for washing machines)
	Irrigation water conservation
A01G 25/02	watering arrangements located above the soil which make use of perforated pipe-lines or pipe-lines with dispensing fittings, e.g. for drip irrigation
A01G 25/06	Watering arrangements making use of perforated pipe-lines located in the soil
A01G 25/16	Control of watering
C12N15/8273	Mutation or genetic engineering; DNA or RNA concerning genetic engineering, vectors, e.g. plasmids, or their isolation, preparation or purification; for drought, cold, salt resistance
	Water conservation in thermoelectric power production
F01K 23/08-10	Combustion heat from one cycle heating the fluid in another cycle
F01D 11	Non-positive-displacement machines or engines, e.g. steam turbines / Preventing or minimizing internal leakage of working fluid, e.g. between stages
	Water distribution
F17D5/02 and E03	Pipe-line systems / Protection or supervision of installations / Preventing, monitoring, or locating loss
F16L55/16 and E03	Devices for covering leaks in pipes or hoses, e.g. hose-menders
	2.1 Supply-side technologies (water availability)
IPC class	**2.2.1 Water collection (rain, surface and ground water)**
	Underground water collection
E03B 5	Use of pumping plants or installations
E03B 3/06-26	Methods or installations for obtaining or collecting drinking water or tap water from underground
	Surface water collection
E03B 9	Methods or installations for drawing-off water
E03B 3/04; 28-38	Methods or installations for obtaining or collecting drinking water or tap water from surface water
	Rainwater water collection
E03B 3/02	Methods or installations for obtaining or collecting drinking water or tap water from rainwater
E03B 3/03	Special vessels for collecting or storing rain-water for use in the household, e.g. water-butts
E03B 3/00	Methods or installations for obtaining or collecting drinking water or tap water; rainwater, surface water, or groundwater

E03B 3/40	Methods or installations for obtaining or collecting drinking water or tap water; rainwater, surface water, or groundwater
	Methods or installations for obtaining or collecting drinking water or tap water; rainwater, surface water, or groundwater **2.2.2. Water storage**
E03B 11	Arrangements or adaptations of tanks for water supply
	2.2.3. Desalination of seawater
E03B 11	Arrangements or adaptations of tanks for water supply
	8. Climate change mitigation technologies related to wastewater treatment or waste management
Y02W10	**8.1 Wastewater treatment**
Y02W 10/00-45	- Biological treatment of water, waste water, or sewage
Y02W 10/00-45	- Sludge processing
Y02W 10/00-45	- Wastewater or sewage treatment systems with climate change mitigation effect characterised by the origin of the energy
	- Valorisation of by-products of wastewater, sewage or sludge processing

App. 2: Keyword search space for (modular) water technologies

Type of water flow	Centralised*	Decentralised*
Water supply	Water supply reservoirs (dams) Groundwater abstraction Surface water abstraction Large-scale transfer of water resources Raw water treatment Real time control and monitoring (leak detection systems) Desalination (reverse osmosis)** Dual supply systems (potable/ non-potable) Direct wastewater reuse (to potable)	Water saving household devices (such as water efficient showerheads, clothes washers, tap flow restrictors etc.) Local/ on-site abstraction On-site desalination (reverse osmosis & capacitive deionisation)** Point of use treatment systems (filters, UV disinfection, softening = in-house equipment for water treatment)** Nano-photocatlysts** Nano-membranes** Nano-adsorbents** Microbial fuel cells **
Stormwater / drainage	Combined sewers (surface water runoff) Separate storm sewers Underground storage systems (connected to sewers) Combined sewer overflows Surface detention systems Gully pots/inserts** Wetlands** Sand filters**	Inlet control (downpipes, butts, ponding)** Swales and filter strips** Pervious surfaces** Soakaways** Infiltration measures** Filter drains** Ponds (stormwater storage)** Constructed wetlands** Sand filters** Vegetated spaces for stormwater collection and treatment Bioretention basins** Sediment basins (*construction*)** Built-in storage** Evaporative sustainable urban drainage systems**
Wastewater & Industrial wastewater	Combined sewer systems Separate sewer systems End-of-pipe wastewater treatment plant Anearobic digester**(basic treatement) Phosphorus elimination and denitrification** (advanced treatement) Real time control and monitoring Membrane bioreactors (aerobic systems)** Sequencing batch reactors (aerobic systems)** In-sewer treatment	Cesspools** Septic tank systems (anaerobic treatment)** Package treatment plants** Reed bed filters** Mound systems** Constructed/ natural wetlands** Sand filters** Membrane bioreactors (aerobic systems)** Membrane aerated biofilm reactors (aerobic systems)** Sequencing batch reactors (aerobic systems)** Living machines (series of emergent vegetation based treatment processes constructed in a greenhouse environment)** Small diameter gravity systems** Low pressure sewers (for toilet & septic tank)** Vacuum toilets** Container-based systems** (P-elimination, denitrification) Air-displacement toilets** Nano-photocatlysts** Nano-membranes**

		Nano-adsorbents** Microbial fuel cells ** Real time control and monitoring
Integration: recycling & reuse	Aquifer storage and recovery (storm- or wastewater reuse) Effluent dual reticulation (dual water supply with non-potable supply coming from treated wastewater) (wastewater reuse) Energy-water systems (heat revovery from wastewater)	Rainwater harvesting (stormwater reuse)** Green roofs (stormwater reuse)** Grey water systems (greywater reuse)** Combined rainwater and greywater recycling (storm- and greywater reuse) Dry & composting toilets (ecosan etc.) (wastewater reuse)** Urine separation (NoMix) (wastewater reuse) Sewer mining (wastewater reuse) Autonomous housing (storm- and wastewater reuse) Container-based systems** Closed water systems (wastewater reuse) Energy-water systems (wastewater reuse) Nano-photocatlysts** Nano-membranes** Nano-adsorbents** Microbial fuel cells ** Real time control

Table App. 2: System boundary for modular water technologies along the dimensions: *type of water flow*, *degree of centralisation**, *novelty*, *industry logic* (modular vs. large-unit)**, based on Makropoulos and Butler (2010), with adjustments based on Singh et al. (2015), Gehrke et al. (2015), Marlow et al. (2013), Sharma et al. (2013), Dubois and Boutin (2018), Dahlgren et al. (2013), (Willis et al., 2013)

Legend:
conventional technology (broadly applied),
novel but used technology (applied in specific contexts but rarely),
novel emerging technology (applied only in prototyping/ pilot projects)
technology potentially promoting a **modular** industry logic
technology** (vs. concepts, approaches, descriptions)

*definition of *decentralised* (in contrast to *centralised*) based on Sharma et al. (2013)

- **Centralised** = dependent on grid-connection
- **Decentralised =** dependent on grid-connection but may be adoptable to grid-based systems, differentiated according to Sharma (2013) in
  - *Onsite* = individual property/ plant scale, systems owned and operated by property owners/ company
  - *Cluster* or *development* scale = common ownership model (two or more dwellings, up to whole development side), treatment close to dwellings
  - *Distributed* systems = service for large development sides, e.g. n> 100 properties, services owned and operated by water utilities

*definition of *modular* (in contrast to large-unit scale) industry logic based on Dahlgren et al. (2013)
- Large-unit scale technologies & infrastructures: custom built, large unit of production (cost savings through unit size) = **economies of unit scale**

- Modular small-unit scale technologies & infrastructures: mass-produced, small units of production (cost saving through flexibility, standardisation and mass production of small units) = **economies of unit numbers**

App. 3:

Full list of newspapers screened:

Africa News	The Sunday Herald (Glasgow)	The Japan News
The Advertiser/Sunday Mail (Adelaide, South Australia)	The Guardian(London)	The Japan Times
Brisbane News	Mining Magazine	Korea Herald
Canberra Times (Australia)	New Scientist	Korea Times
Hobart Mercury/Sunday Tasmanian (Australia)	The Daily Mail and Mail on Sunday (London)	New Straits Times (Malaysia)
Herald Sun/Sunday Herald Sun (Melbourne, Australia)	The Observer(London)	The Edge Malaysia
The Age (Melbourne, Australia)	The Investors Chronicle	New Era (Windhoek)
The West Australian (Perth)	The Independent (United Kingdom)	The Namibian (Windhoek)
Sydney Morning Herald (Australia)	BBC Monitoring: International Reports	Daily Trust (Abuja)
The Australian	The Daily Telegraph (London)	Het Financieele Dagblad (English)*
Australian Financial Review	The Engineer*	The New Zealand Herald
Northern Territory News (Australia)	The Mirror (The Daily Mirror and The Sunday Mirror)	The Press (Christchurch, New Zealand)
The Courier Mail/The Sunday Mail (Australia)	The Sunday Telegraph (London)	The Dominion (Wellington)*
The Daily Telegraph (Australia)	Accountancy Age (UK)*	The Dominion Post (Wellington, New Zealand)
The Gazette (Montreal)	Airline Business	The Evening Post (Wellington)*
Ottawa Citizen	Marketing - UK*	BusinessWorld
National Post's Financial Post & FP Investing (Canada)	mirror.co.uk	Polish News Bulletin
The Globe and Mail (Canada)	standard.co.uk	Sunday Times (South Africa)
The Toronto Star	telegraph.co.uk	GroundUp (Cape Town)
National Post (f/k/a The Financial Post)(Canada)	The Evening Standard (London)	The Conversation Africa (Johannesburg)
South China Morning Post	The Herald (Glasgow)	Business Day (South Africa)
Lianhe Zaobao	Travel Trade Gazette UK & Ireland*	Financial Mail (South Africa)
Baltic News Service	Ghanaian Chronicle (Accra)	The Moscow News (RIA Novosti)*
Addis Fortune (Addis Ababa)	The Times of India (TOI)	The Moscow Times*
Maghreb Confidential	Hindustan Times	Moscow News*
Belfast News Letter*	The Economic Times	The New Times Kigali

Belfast Telegraph	The Irish Times	The Straits Times (Singapore)
Belfast Telegraph Online	The Jerusalem Post	The Edge Singapore
Birmingham Evening Mail	The Jerusalem Report	The Business Times Singapore
Birmingham Post	Nikkei Asian Review	The Nation (Thailand)

The Christian Science Monitor	Computer Weekly*	MTI Econews*
The Philadelphia Inquirer	Computing	Music Week*
The Philadelphia Inquirer - Most Recent Two Weeks	Contract Journal*	MWP Advanced Manufacturing*
Advertising Age	Control and Instrumentation*	Natural Gas Week
Automotive News	Creative Review*	New Media Age*
The New York Times	Daily Record and Sunday Mail	New Musical Express
Chemical Week	Daily Variety*	Newsweek
The New York Times - International Edition	Design Engineering*	Off Licence News*
Accounting Today	Design Week*	Plastics News (tm)
ADWEEK	Electronics Weekly	Platts Energy Business & Technology*
The New Yorker	Employee Benefits	Platts Megawatt Daily
Waste News*	Estates Gazette	PR Week
Business Monitor News	Euromoney	Precision Marketing*
Tampa Bay Times	EXE*	Process Engineering*
The Washington Post	Farmers Weekly	Professional Broking*
The San Francisco Chronicle	Financial Adviser	Retail Week*
Daily News (New York)	Financial Director*	Revolution*
Los Angeles Times	Flight International	Rubber & Plastics News
PR Week (US)*	Industry Week*	Satellite Week*
USA Today	Insurance Age*	TechNews*
The Herald (Harare)	International Money Marketing*	The Banker
Audio Week*	ITAR-TASS	The Business*
Billboard	Lawyers Weekly*	The Deal Pipeline
Brand Strategy*	Legal Week	The Electricity Journal
Builder*	Management Today	The Express
Business & Finance Magazine*	Marketing Week	The Grocer
Campaign*	Mergers and Acquisitions, The Dealmaker's Journal	The Lawyer
CFO	Middle East Newsfile (Moneyclips)*	The People
City A.M.	Mobile Communications Report*	The Pharma Letter
CMP Information	Money Marketing	The Weekly Times
Xtreme Information*	What's new in Industry*	Wall Street Journal Abstracts

App. 4: Search term query to identify articles

Terms: (((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR smart OR distributed OR integrated OR household) PRE/2 (water OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR rainwater OR seawater) PRE/2 (recycling OR reuse OR treatment OR infrastructure OR desalination)) OR ((water OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR rainwater OR seawater) PRE/1 (recycling OR reuse OR reclamation OR harvesting OR desalination)) OR (membrane PRE/1 bioreactor) OR (sequencing PRE/1 batch PRE/1 reactor) OR (microbial PRE/1 fuel PRE/1 cell) OR (membrane PRE/1 aerated PRE/1 biofilm PRE/1 reactor) OR (nano PRE/1 membrane) OR (nano PRE/1 adsorbent) OR (nano PRE/1 photocatalyst) OR (septic PRE/1 tank) OR (package PRE/1 treatment PRE/1 plant) OR (point PRE/2 use PRE/1 treatment) OR ((dry OR composting) PRE/1 toilet) OR (dual PRE/1 flush PRE/1 (plumb! OR toilet)) OR ((urine OR source) PRE/1 separation) OR (water PRE/1 saving PRE/1 device) OR (inlet PRE/1 control) OR (infiltration PRE/1 measure) OR (sustainable PRE/1 urban PRE/1 drainage) OR (NoMix) OR (jokhasou) OR (ecosan) OR (ecological PRE/1 sanitation) OR (water PRE/1 sensitive PRE/1 cities) OR (green PRE/1 roof) OR (water W/7 (resource PRE/1 recovery)) OR (reverse PRE/1 osmosis) OR (zero PRE/1 liquid PRE/1 discharge) OR (capacitive PRE/1 deionisation) OR (desalination) OR ((direct OR indirect) PRE/2 potable reuse) OR (real PRE/1 time PRE/1 control) OR (autonomous PRE/1 housing) OR (closed PRE/1 water PRE/1 system) OR (energy PRE/1 water PRE/1 system) AND HLEAD(water) AND ATLEAST3 (water) & ATLEAST2 (treatment))

App. 5: Indicator calculations

Conducive narrative share (discursive indicator for regime strength)

$$x_C^{conducive} = \frac{\sum \boldsymbol{FC_{Lmod}} + \sum \boldsymbol{FC_{DLcon}}}{\sum \boldsymbol{FC}}$$

where $x_C^{conducive\ narrative\ share}$ denotes the audience-based indicator for the conducive narrative share, which is given by the sum of all legitimising narrative uses towards modular technologies $\boldsymbol{FC_{Lmod}}$ and all de-legitimising narrative uses towards conventional technologies $\boldsymbol{FC_{DLcon}}$ divided by the sum of all narratives uses in the respective discourse.

Attraction indicator

$$\alpha_C^{attraction} = \left(\frac{(\sum \boldsymbol{FC_{Lemod}} + \sum \boldsymbol{FC_{DLecon}})}{(\sum \boldsymbol{FC_{Lmod}} + \sum \boldsymbol{FC_{DLcon}})} \right)$$

where α denotes the audience-based indicator for *attraction*, given by the sum of all narratives by extra-regional actors conducive to modular technologies through legitimation or de-legitimation of conventional technologies $(\sum \boldsymbol{FC_{Lemod}} + \sum \boldsymbol{FC_{DLecon}})$ divided by all narrative uses conducive to modular technologies $(\sum \boldsymbol{FC_{Lmod}} + \sum \boldsymbol{FC_{DLcon}})$ overall in the local media coverage.

Absorption indicator

$$\beta_{AC}^{absorption} = \left(\frac{(\sum \boldsymbol{FAC_{absorbedLmod}} + \sum \boldsymbol{FAC_{absorbedDLcon}})}{(\sum \boldsymbol{FAC_{Lmod}} + \sum \boldsymbol{FAC_{DLcon}})}\right))$$

Where $(\sum \boldsymbol{FAC_{absorbedLmod}} + \sum \boldsymbol{FAC_{absorbedDLcon}})$ refers to all conducive narratives absorbed from abroad by local actors addressing a local audience and $(\sum \boldsymbol{FAC_{Lmod}} + \sum \boldsymbol{FAC_{DLcon}})$ refers to the overall amount of narrative uses by local actors in the local media.

Endogenous legitimation indicator

$$\gamma_{AC}^{endogenous} = 1 - \left(\alpha_{C}^{attraction} + \beta_{AC}^{absorption}\right)$$

Export indicator

$$\beta_{A}^{export\ score} = \left(\frac{(\sum \boldsymbol{FA_{Lemod}} + \sum \boldsymbol{FA_{DLecon}})}{(\sum \boldsymbol{FA_{Lmod}} + \sum \boldsymbol{FA_{DLcon}})}\right)$$

Where $(\sum \boldsymbol{FA_{Lemod}} + \sum \boldsymbol{FA_{DLecon}})$ refers to all conducive narratives exported by local actors to non-local audiences and $(\sum \boldsymbol{FA_{Lmod}} + \sum \boldsymbol{FA_{DLcon}})$ refers to the overall amount of conducive narratives used by local actors.