Winners and losers during transition: the case of urban water and energy systems in Sweden

Timos Karpouzoglou[1], Pär Blomkvist[2], Farzin Golzar[3], David Nilsson[1], Semida Silveira[3], Jörgen Wallin[3]

[1]Division of History of Science, Technology & Enviroment, KTH Royal Institute of Technology, Sweden
[2]Division of Organization and Management, Mälardalen University, Sweden
[3]Department of Energy Technology, KTH Royal Institute of Technology, Sweden

Globally, there is an increasing consensus around the need to realise deep transformations in vital sectors of society such as those related to urban water supply and energy, particularly in cities where the largest share of the global population is living. Taking the example of recent changes in energy requirements for buildings in Sweden, the government has proposed that, by 2021, all new houses shall have" near zero" energy demand, which for a multifamily house in Stockholm translates into a primary energy demand of 85 kWh /m2 per year. This has generated a new kind of niche experimentation in the building sector that cuts across traditionally disconnected domains of innovation around water and energy. For example, technologies around greywater re-use and heat recovery from wastewater have become associated with reduction in water use and important energy gains. These innovations propel private users and organisations - notably in the real estate sector - towards new investments as part of realising ambitious energy and water targets. As end-users of networked water and energy services, actors make technology-decisions that save energy, water and reduce their dependence on centralised network providers. But this also causes negative commercial and physical effects on the established networked configurations of water and energy, in the form of reduced economic revenue, less heat circulation, and colder wastewater causing problems in the treatment plants. In our study we focus on the winners and losers of energy and water transition in Sweden, to learn about how transition in energy and water is evolving and why it is being negotiated along particular trajectories by a range of relevant actors.

Keywords: interface misalignment; critical interface; regime actor; niche actor; water energy nexus; greywater reuse

1. Introduction

As the world braces to meet the need for sustainability transition and the Paris agreement on climate change, within the building sector diverse actors such as individual property owners and multi-family property companies are experimenting with innovations to make buildings more energy and water efficient. On a global level, the building sector contributes 39% of the annual greenhouse gas emissions, when factoring in construction, operation, and energy consumption for heating and cooling (International Energy Agency and The United Nations Environment Programme, 2018). The pressure for lower energy consumption also fuses with other challenges such as security of water supply. Large parts of the world experience increasing water scarcity and variability due to climate change and high water demand, and the United Nations has estimated that globally, two billion people live in areas classified as water scarce (UN Water, 2018). Water and energy are interlinked in a multitude of ways often referred to as the global water-energy nexus (Gleick, 1994; Fang and Chen, 2017). When innovations and socio-technical transformations begin to pick up in one part of this nexus, inevitably it has repercussions on other parts.

Energy and water infrastructures are not only vital for society, and for all life. Over the past century these infrastructures have aggregated into socio-technical constructs of very large scale, naturalised into society as “circulatory systems of modernity” to cite (Edwards, 2003, p. 185). With time, they have come to span regions and countries, arguably even forming global regimes (Hughes, 1993; Fuenfschilling and Binz, 2018). Historically, their growth phase was accompanied by a commensurate expansion of organisational structure centered on a few system builders, such as public utility companies or private enterprises under state regulation. While infrastructural development in Europe shows considerable dynamism over the past century, including deregulation, privatisation and scaling back of state responsibilities, the large incumbent regime actors are still important for how sustainability transitions will play out (Högselius, Kaijser and van der Vleuten, 2015; Van der Vleuten, 2019). However, even as incumbent regime actors often enjoy the privileges of natural monopoly, their powers are limited at the consumer level. Innovation taking place at the niche level, driven locally by property owners, is therefore hard to control by centrally placed actors like an electricity company or a water and sewerage utility. Yet, innovations on the margin can have severe disruptive effects on a large infrastructural system, as demonstrated by the solar panel revolution (Green and Newman, 2017). In such situations, a power struggle emerges between different actors regarding not just what a sustainability transition should be about, but who should drive and control it (Lee and Hess, 2019). In particular, at the core of this struggle is the question of whether a transition should be steered by incumbent regime actors or by new niche actors such as building companies and private homeowners.

In Sweden we have studied real cases where these types of interactions are taking a more pronounced effect. If we turn to energy recovery in the form of heat from wastewater, this is an area that has been traditionally controlled by incumbent regime actors, namely Stockholm Vatten och Avfall (SVoA), the Stockholm Water and Wastewater Authority, and Stockholm Exergi (Exergi), the company for District Heating supply. However, in recent years more installations are introduced by niche actors within the building sector (Arnell, Lundin and Jeppson, 2017). Recovery of not just energy but also greywater (from showers) is now being tested within rented properties in Gothenburg (Wallin, Knutsson and Karpouzoglou, 2020). Another interesting example in Sweden is in the development of small-grids for water supply and sewerage collection. In the coastal communities of Värmdö outside Stockholm which experiences seasonal regional water scarcity, private home owners have steered these innovations taking up a role which is usually controlled by the municipality (Nygren and Hjort, 2020). What connects these various initiatives is that despite the fact that they are innovative, at the same time they are challenging previously established relationships between actors in ways that potentially generate conflicting visions of sustainable energy and water transitions.

In this paper we are interested in exploring how the ongoing innovation activity in energy and water systems is changing the relationship between regime and niche actors. Our objective is to identify with the use of aforementioned real case examples, both tangible and imagined conflicts between actors in the water-energy nexus of city-building. The winners and losers metaphor is therefore useful for portraying the context of some of these conflicts within a heterogeneous actor landscape. We also turn to ways in which conflicts can be addressed and the various interests to become better aligned with each other.

The next section outlines our theoretical framework and a short survey of the field, followed by a section describing the overall approach and methodology. Section four presents our preliminary findings from three case studies where recovery of energy and water at property level is under way. In section five we discuss the findings and reflect on what implications they might have for services delivery sustainability and equality, as we envisage the outcome of a 'winners' versus 'losers' re-distribution also will be affected by tacit social factors and the political ecology of cities. The paper ends with our conclusions and forward looking suggestions for continued research.

2. Theoretical framework: Winners and losers in water and energy transitions

Our theoretical framework is inspired by the Multi-Level Perspective (MLP)(Geels, 2004) and innovation system research (Hillman *et al.*, 2011). In particular, we draw inspiration from these literatures to investigate niche-regime actor interactions in water and energy infrastructures. However, we are also drawing from recent research in the wider field of transitions research and also including perspectives from geography, history and institutional theory a way to develop deeper insights into these interactions (Lawhon and Murphy, 2012; Fuenfschilling and Truffer, 2016; van Welie, Truffer and Gebauer, 2019).

In earlier research, we have also established what we call the critical interface as the boundary area between the regime and the niche level (Blomkvist and Nilsson, 2017; Blomkvist *et al.*, 2019). However, the interaction of niche and regime actors within the critical interface is far less clearly demarcated and hierarchical in comparison to how it was first conceived in earlier work surrounding for instance work around the MLP (Geels, 2004). Regime actors themselves may indeed be involved in niche-level innovation together with diverse users of innovation (Blomkvist *et al.*, 2019). It is worth noticing that the critical interface has been mainly applied in developing countries where boundaries between the niche and the regime tend to remain porous and are shifting dynamically. However, interestingly, we observe a similar blurring of these boundaries occurring in developed countries such as Sweden. Hence, from a conceptual standpoint we are also interested in expanding the critical interface as a way to theorise some of these challenges as they are unfolding in developed country settings.

The critical interface therefore constructively expands on the MLP by elaborating the interaction of these various actors in terms of the historical, geographical and institutional space that they occupy and which they have to negotiate as part of an innovation process, see also Figure 1. Regime actors have also been understood as 'ambidextrous' innovation agents having to engage with both niche and regime activities simultaneously (Blomkvist *et al.*, 2019; van Welie, Truffer and Gebauer, 2019).

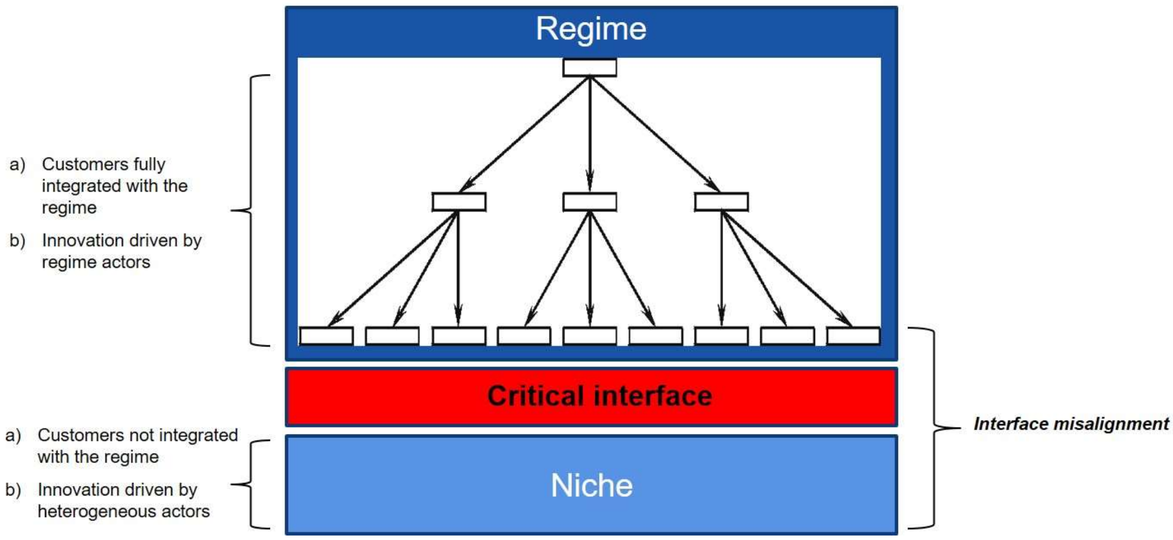

Figure 1: Conceptual Framework, adapted from Blomqvist et al. 2019

The situation forces the actors to align between system levels, and we introduce a concept derived from the MLP that we call interface alignment/misalignment (Geels and Schot, 2007). The regime actor is traditionally interested in avoiding technical and institutional mismatch in the system – to align system components within the system, including business models and cost-recovery schemes

(Summerton, 1994; Tongur and Engwall, 2014). We see however that new and more pluralistic provision modes, aspects of diversity, self-organisation, power and ideals challenges the regime actors' traditional alignment work (Graham and Marvin, 2001; Silver, 2015; Monstadt and Schramm, 2017; Fuenfschilling and Binz, 2018; van Welie, Truffer and Gebauer, 2019). This is also particularly prominent in water and energy infrastructure development where rapid innovation is taking place in infrastructural systems outside the boundaries of regime actors. These innovation activities are increasingly induced from the niche level, by diverse users, prompting some scholars to talk of 'inverse infrastructures' (Egyedi and Mehos, 2012). As pointed out in a recent Economist article about the transition in electricity networks in Europe: "for the last 100 years everyone has made money upstream. Now the added value is coming downstream"(The Economist, 2017).

Importantly, interface alignment/misalignment can direct our attention to how regime actors in the existing water system work to fit (align) the plurality of water and energy provision solutions available at the local level to the old system, its technology, business models and institutions. (Blomkvist and Nilsson, 2017; Blomkvist *et al.*, 2019). Interface misalignments can relate for instance to regime actors incomplete knowledge of important contextual factors at the local level, where an innovation is implemented (Blomkvist *et al.*, 2019). In this paper, we are primarily looking at such kind of interface misalignments between niche and regime level actors in relation to infrastructures in Sweden.

Interface misalignments can generate risks for an unequal playing field of actors and potential for winners and losers. Interface misalignments can be related to deep ideology and particular ways in which systems are imagined (Stirling, 2014; Kanger and Schot, 2018; Van der Vleuten, 2019). Hence, regime actors may remain in a stagnated situation stuck within an old business as usual scenario while non-traditional actors aspire to innovate away from the old system thus creating a risk for possible disruptive situations for the entire system. It is important to note that possibilities for coexistence can and should be created between the various actors so that conflicts of interest and potential winners and losers can be addressed and their interests negotiated. Regime actors can for instance engage in 'ambidextrous' innovation strategies that allow for business as usual while creating incentives for non-traditional models to flourish (Blomkvist *et al.*, 2019). Niche actors can in turn continue to innovate while complying to regularly updated guidelines and regulations that ensure not only niche level success but also entire system level integrity.

3. Method and approach

The approach aims to understand how regime and niche actors are trying to influence the water and energy transition process in the Swedish urban setting using a case study approach (Yin, 2012). Following the theoretical framework, we use the case studies to illustrate real examples of interface misalignments between niche and regime level actors. An understanding of interface misalignments is in turn used to generate insights about power struggles in transitions and winners and losers.

In order to investigate the case studies, we have collected data from three different cases of water and energy systems. We look at one case of heat recovery from wastewater in Stockholm municipality. A second case of greywater reuse in Gothenburg municipality. A third case, of small-grids for water and sewerage in Värmdö municipality. In developing the case studies, qualitative and quantitative data was collected using different methodologies such as field observations and semi-structured actor interviews, technical performance and quantitative scenarios.

The key actors who we address in our case studies are to be found at the niche and regime level. At the niche level we targeted mainly actors such as large and small property owners. At the regime level, we focused primarily on the role of municipalities and their affiliated water and sewerage utilities and energy utility companies. Technical performances of the technologies have focused mainly on operational performance such as in terms of energy and water recovery. Quantitative scenarios are based on modelling different projections of adoption of the technologies and assessing disruptive effects to the entire system (for energy and water delivery).

4. Case studies

4.1. Property level wastewater heat recovery, Stockholm municipality

4.1.1 System description

Wastewater heat recovery is principally based on extracting energy which is stored in the form of heat in outgoing wastewater. In the urban energy cycle recovering this heat which is stored in the wastewater is energy that would otherwise be lost, and therefore returning the heat back to the energy cycle has been noted to have a role in city sustainable energy transitions (Frijns, Hofman and Nederlof, 2013). Recent focus of building regulations in improving energy efficiency of buildings have also created new conditions for expansion of heat recovery systems, particularly at property level (Bertrand, Aggoune and Maréchal, 2017; Sitzenfrei, Hillebrand and Rauch, 2017).

In energy and water infrastructure planning, regime actors such as water and energy utilities have traditionally been the principal actors involved in recovering energy from wastewater. Traditionally, this tends to happen in a centralised manner, such as through installations located in highly centralised large-scale wastewater treatment plants (Kretschmer, Simperler and Ertl, 2016). In contrast to the large scale systems, in Stockholm, we have studied more closely the heterogeneous niche level actors such as property owners and technology developers that are also increasingly involved in pilot projects for recovering heat from wastewater at property level.

One such property level wastewater heat recovery system has been studied in the residential district of Töfsingedalen that is situated in Norra Djurgårdsstaden in Stockholm Sweden. This is a multifamily house owned by the property developer, Stockholmshem and consisting of 141 apartments, one preschool and two stores. The wastewater heat recovery heat exchanger is installed so that all the wastewater from the building is passing through it. The technical performance for this system has shown that this installation could recover approximately 17 % of the available heat in the wastewater. The heat recovered from the wastewater is used principally to preheat the domestic hot water, see also Figure 2.

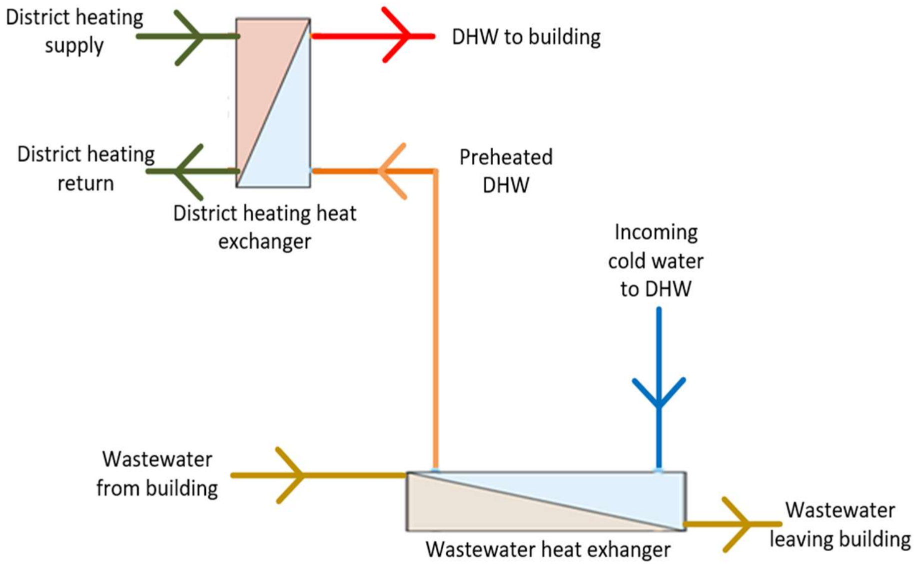

Figure 2 - Schematic of heat recovery system

4.1.2 Interface misalignments

The niche actors we identified through this case are very interested in further upscaling on property heat recovery as this can reduce the buildings demand for 'raw heat'. In addition, by recovering heat locally they no longer perceive themselves as passive consumers of electricity as they also now producing new energy in the form of heat. Explicit connections are made in interviews with property developers on the role of heat recovery in supporting property owners to meet ambitious energy targets.

The key regime actors in this case are Exergi, which is the energy utility of Stockholm municipality. Exergi provides heating to the majority of Stockholm residents. Another important regime actor is SVoA, which is the Stockholm Water Utility Company providing drinking water supply to the city of Stockholm but also treating the wastewater through two centralised large scale wastewater treatment plants in Bromma and Henriksdal.

In the study of Töfsigenalen we have observed a potential for interface misalignment in the system between the aforementioned regime and the niche actors. The main misalignment concerns the way in which gains and losses in terms of energy savings become re-distributed between the niche and regime level as a result of on property heat recovery. In a scenario we have looked at where

40% of the existing buildings stock in Stockholm installed property heat recovery systems, raw heat demand in buildings would decrease by 6% (96 GWh.year^{-1}). In this scenario, niche actors can be regarded as winners due to the reduction of heat demand. In this scenario, significant levels of heat recovery at the property level can lead to decreases in the temperature of the wastewater entering the centralised wastewater treatment plants like Henriksdal disrupting the operations of SVoA. Moreover, installing heat exchangers in 40% of buildings would result in 2^{0}C decrease in influent temperature and this could increase the heat demand at the treatment plant by 6% (0.71 GWh.year^{-1}). Exergi would also experience a decrease of 11% (176 GWh.year^{-1}) of recoverable heat compared to current conditions because heat is recovered at the property level. This means that Exergi would have to compensate 79 GWh.year^{-1} using other energy resources (Golzar and Silveira, 2020). The two regime actors can therefore be regarded as losers in this situation since they would have to develop strategies to compensate for the loss of energy in the form of heat from the water.

4.2. Greywater reuse, Gothenburg municipality

4.2.1 System description

Greywater reutilisation is not widespread in Sweden but experiences from other countries suggests that this is an area typically organised at the regime level around water reuse for irrigation and artificial groundwater infiltration (Angelakis and Gikas, 2014). However, the purpose of greywater reuse for hygiene purposes which has been explored in this case, is a relatively recent concept that opens up scope for niche level actors (Lu and Leung, 2003; Chaillou *et al.*, 2011).

A pilot plant for greywater reutilisation for hygiene purposes is installed in a multifamily building in Gothenburg, Sweden. The building is owned by HSB, a cooperative association for housing in Sweden. The building is situated on the campus of Chalmers University of Technology and therefore the inhabitants are primarily students that are renting the apartments from HSB. In the pilot plant, the treatment and recovery system are made up of several standard "of the shelf" components, each with its own purpose. The number of components and the grade of the components heavily depend on the demand of treatment. Since there are no regulations in Sweden determining the treatment level of hot tap water, the system creator decided to aim for drinking quality as a level of treatment, see also Figure 3.

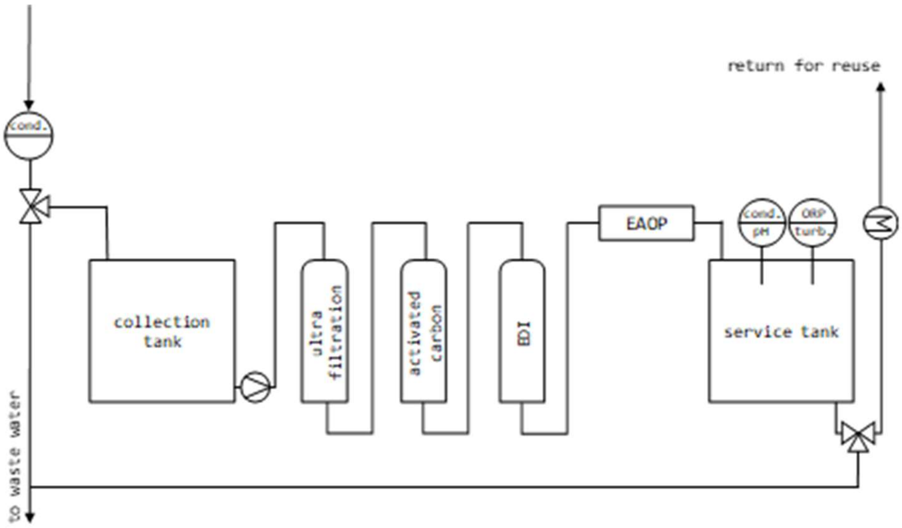

Figure 3 - Pilot plant setup for greywater reclamation

In the pilot installation, greywater is collected from six shared bathroom showers. The system is protected from highly contaminated flows by a conductivity sensor. If the value of the conductivity exceeds a maximum limit, greywater is diverted to the municipal wastewater until the conductivity falls below the maximum allowed value. In normal operation, the greywater is collected in a feed buffer tank. Treated greywater is collected in a domestic hot water tank for use as preheated water when there is a demand. From the service tank, the water is pumped and directly heated on demand. The pilot plant has a treatment capacity of around 3.8 liters per minute. Our own investigations of the installation indicate that 91 % of the water used in the showers was reclaimed and that the energy demand for tap water heating was also reduced by 55 %. In economic terms, the return of investment for the system and installation was shown to be 3.7 years. This is a reasonably sound return of investment period that is comparable to other more commercialised property systems such as geothermal heating systems (Wallin, Knutsson and Karpouzoglou, 2020).

4.2.2 Interface misalignments

Looking at the pilot installation and the results from Gothenburg, it can be concluded that the niche actor has both economic and water saving incentives to install a system for greywater reuse. In contrast to the previous case however, interface misalignments are weaker or at least not as explicitly visible yet. We foresee that interface misalignments can however intensify if greywater recovery is tested in more buildings and taken up by other property owners.

The two most relevant regime actors at this stage are the water and energy utility companies of Gothenburg municipality. A misalignment can occur because the wastewater sewer collection system begins to receive a lower inflow of wastewater which in turn can increase the risk of clogging in the sewer network, thereby increasing maintenance time and costs by the regime actors. Given that greywater also contains energy in the form of heat in addition to the volume of water, interface misalignments that relate to the fact that less heat is reaching the treatment plants (similar to the case in section 4.1.2) can also create risks for regime actors. In this case, misalignments could result in different outcomes for winners and losers. Niche actors can be viewed as winners in the short to medium term from the perspective of water savings. However, in the long term, water saving benefits can be displaced by high economic costs associated with overtreating the water in order to match the legislated drinking water quality standards. Over time therefore niche actors can change from winners to losers. In the case of the regime actors the opposite can be true. In the short term, they are likely to be losers in transitions as their business models and operations are not aligned with greywater recovery at the property level. In the long term they can turn into winners because they need to treat less volumes of greywater than before.

4.3. Small-grid water and sewerage, Värmdö municipality

4.3.1 System Description

Small-grid water and sewerage systems are of rising interest in more remote parts of Sweden that are typically not served by municipal systems. This is either because it is too expensive for municipalities to extend their networks to these locations or because of the inaccessibility of these regions. In Värmdö, we have studied one such small-grid system in one locality, Aspvik, where there are 170 private properties equally distributed between permanent and vacation properties. Due to its proximity to Stockholm, Aspvik is an attractive location both for permanent and holiday property owners.

A small-grid has been designed that replaces private wells and individual sewage solutions with a community managed network that is also connected to the main municipal grid for water supply and sewerage collection. The technology chosen in the Aspvik case for the sewerage collection was a traditional low-pressure sewage (LPS) system using a tank and pumping technology at each property. This technology is suitable when the ground conditions provide a challenge to have a gravity-based system. It also enables the sewage pipes to be installed shallower and thereby reducing the demand of excavation. In that sense, it is a hybrid model that borrows features from both centralised and decentralised approaches for water and sewerage (Nygren and Hjort, 2020).

4.3.2 Interface misalignments

An interesting distinction of this system from the previously discussed is that in this project a conscious consideration of interface misalignments fed into the design of the innovation from the early inception of the project. This means that synergies were pursued between niche and regime actors from the beginning so as to harmonise misalignments. This was the result of ‘ambidextrous’ strategies that allowed regime actors for maintaining their business as usual model of service delivery while creating space for a non-traditional service delivery experiment. The niche actors in turn were proactively engaged with regime actors in the design of the experiment and ensured alignment with the entire system.

Specifically, there has been an active and continuous dialogue between the two economic associations (Räknäs VA-förening and Risholmen & Sjötorp VA-förening), which are compromising all Aspvik property owners and are managing the project, and the municipality of Värmdö. This means that interface misalignments have been identified and resolved. For instance, one interface misalignment that was important for the municipality and which became addressed by niche actors was the risk of a service delivery gap between the niche and the regime. This could happen for instance if the associations decided to leave behind some property owners by not including them in the project. Hence, it was immediately realised that full participation by all Aspvik property owners was necessary and became a condition for support from Värmdö municipality.

A distinction of this case with the previous therefore is that this case is not necessarily disruptive to the social-technical regime actors. In contrast, the Aspvik model functions more or less as an "add-on" or an "adapter" to the regime, making it possible to provide water and sanitation in areas far from the piped system. Hence, these two, the traditional municipal system and the Aspvik small-grid coexist and prosper from each other. We therefore see more opportunity here for an equal playing field where there is no clear loser, rather winners on both the niche and the regime side of the transition spectrum.

5. Discussion and concluding remarks

In this article we have described three different cases of innovation in the water and energy sector in Sweden. These three cases are significant in terms of energy and water transitions since they create opportunities for new kinds of niche actors to influence future transition pathways. At the same time they are illustrative of potentially disruptive innovation pathways that can be challenging for traditional regime actors such as municipalities and energy and water utilities to assimilate. Thus, as we have observed, these cases are illustrative of an unequal playing field of actors where we see winners and losers pursuing competing interests in an unfolding power struggle for dominance in the energy and water system.

We have identified a critical interface between the niche and the regime where these power struggles tend to be played out. While niche experiments are generally upheld in the context of sustainable transition, focusing on the critical interface helps to widen the view of what niche experiments actually entail for niche actors but also wider critical infrastructure systems. Moreover, regime actors in particular need to relate to these experiments and to some degree be able to assimilate them within their own business models. In the first two cases of heat recovery and greywater recovery we identify a certain lack of preparedness and ability of the system to assimilate these experiments while in the case of small-grid networks these tend to be more easily assimilated. In all the cases we see potential for power struggle often manifested in the form of antagonistic and contested views about the distribution of risks and benefits. While niche actors generally see significant benefits with organising water and energy services from below, regime actors may remain more sceptical or assume that the regime is the most desirable entry point for organising the delivery of essential water and energy infrastructures. As noted by Lee and Hess (2019) in the case of solar energy transition, incumbents tend to resist new actors and technologies when these are construed as a threat to the organisation's dominance, even when policy is conducive for a technological transition.

To understand these interactions at a deeper level it is useful to understand the scope for alignment and misalignment between the niche and the regime. While some degree of misalignment is to be expected between new and older innovation set-ups, much depends on how these misalignments are going to be dealt with. If misalignments remain unaddressed for a long time in what is actually a rapid transitional context, the scope for an unequal playing field of winners and losers is amplified which in turn entails a greater risk for disruptiveness to essential infrastructure operations, such as energy, water supply or wastewater treatment. There is no question that niche experiments are going to be essential to achieve ambitious energy and water goals but what we argue is that these experiments have to become better aligned with traditional systems during their different phases of innovation (i.e. testing, adoption, diffusion).

It is expected that during these different phases the winners and losers also change (i.e. a winner in the adoption phase might become a loser at the diffusion phase). Hence there is a need to be aware that these interactions are continuously subject to change. Geographical factors as well as infrastructural prestige also play a role (Lawhon and Murphy, 2012; Rodríguez-Pose, Crescenzi and Di Cataldo, 2018). Stockholm and Gothenburg are municipalities that have invested heavily in fairly centralised but widely regarded as prestigious systems for water and energy delivery and are in that way likely to be more resistant towards new models from below. Värmdö municipality, a smaller and less well-resourced municipality, perceives these models from below with less resistance and as welcomed adapters to their own operations. None of these municipalities has however invested in a dedicated boundary organisation to deal with misalignments and addressing winners and losers.

Niche experiments such as the ones described here are already multiplying across different regions of Sweden and are in various phases of development. Dealing therefore with misalignments is going to be increasingly important and has to be done in parallel with the important work of infrastructural innovation. Right now there is no significant actor to deal with these misalignments. We therefore see an important opportunity here for an actor that can better understand what is happening both inside and outside of the regime (Fuenfschilling and Truffer, 2014; Hansen *et al.*, 2018). The work which would be required by such an actor we perceive as being more institutional rather than technological by raising the understanding of the kind of negotiations, positions, and power struggles that are going on in the critical interface.

6. Acknowledgements

This study is carried out within the project SEQWENS: *Ensuring sustainability and equality of water and energy systems during actor-driven disruptive innovation*, financed by the Swedish research council FORMAS, Grant no. 2018-00239. We wish to thank all participants from industry and authorities in the reference group, our respondents and our four master's theses students.

7. References

Angelakis, A. N. and Gikas, P. (2014) 'Water reuse: overview of current practices and trends in the world with emphasis on EU states', *Water Utility Journal*. academia.edu, 8(67), p. e78. Available at: http://www.academia.edu/download/36076022/ANGELAKIS___GIKAS_WUJ_2014_08_07.pdf

Arnell, M., Lundin, E. and Jeppson, U. (2017) *Sustainability Analysis for Wastewater Heat Recovery – Literature Review*. Lund: Lund University. doi: 10.13140/RG.2.2.27365.91364.

Bertrand, A., Aggoune, R. and Maréchal, F. (2017) 'In-building waste water heat recovery: An urban-scale method for the characterisation of water streams and the assessment of energy savings and costs', *Applied energy*, 192, pp. 110–125. doi: 10.1016/j.apenergy.2017.01.096.

Blomkvist, P. *et al.* (2019) 'Bridging the critical interface : Ambidextrous innovation for water provision in Nairobi's informal settlements', *Technology in society*. doi: 10.1016/j.techsoc.2019.101221.

Blomkvist, P. and Nilsson, D. (2017) 'On the need for system alignment in large water infrastructure: Understanding infrastructure dynamics in Nairobi, Kenya', *Water Alternatives*, 10(2), pp. 283–302. Available at: http://www.water-alternatives.org/index.php/alldoc/articles/vol10/v10issue2/356-a10-2-6/file.

Chaillou, K. *et al.* (2011) 'Bathroom greywater characterization and potential treatments for reuse', *Water, Air, & Soil Pollution: Focus*. Springer, 215(1-4), pp. 31–42. Available at: https://idp.springer.com/authorize/casa?redirect_uri=https://link.springer.com/content/pdf/10.1007/s11270-010-0454-5.pdf&casa_token=QXRBZYrlw7YAAAAA:xcmzqp-ydarY0np1q-Ubn2pjpGZuesdSnLuVZYmALPcjJqIGSGKbmiTy8mA7SYImvkvQTHnz14Xf7zk.

Edwards, P. N. (2003) 'Infrastructure and modernity: Force, time, and social organization in the history of sociotechnical systems', *Modernity and technology*. MIT Press Cambridge, MA, 1, pp. 185–226. Available at: https://books.google.com/books?hl=en&lr=&id=DV8IGo88aTQC&oi=fnd&pg=PA185&dq=Infrastructure+and+modernity+Force+Time+and+Social+Organisation+in+the+History+of+Sociotechnical+Systems&ots=DDdRGYTr05&sig=Kt7vfIyZl9jW8AeM_1ScBiTEG5I.

Egyedi, T. M. and Mehos, D. C. (2012) *Inverse Infrastructures: Disrupting Networks from Below*. Edward Elgar Publishing. Available at: https://play.google.com/store/books/details?id=wG4c7s8uKjUC.

Fang, D. and Chen, B. (2017) 'Linkage analysis for the water–energy nexus of city', *Applied energy*, 189, pp. 770–779. doi: 10.1016/j.apenergy.2016.04.020.

Frijns, J., Hofman, J. and Nederlof, M. (2013) 'The potential of (waste)water as energy carrier', *Energy Conversion & Management*, 65, pp. 357–363. doi: 10.1016/j.enconman.2012.08.023.

Fuenfschilling, L. and Binz, C. (2018) 'Global socio-technical regimes', *Research policy*. North-Holland, 47(4), pp. 735–749. doi: 10.1016/J.RESPOL.2018.02.003.

Fuenfschilling, L. and Truffer, B. (2014) 'The structuration of socio-technical regimes — Conceptual foundations from institutional theory', *Research policy*. Elsevier B.V., 43(4), pp. 772–791. doi: 10.1016/j.respol.2013.10.010.

Fuenfschilling, L. and Truffer, B. (2016) 'The interplay of institutions, actors and technologies in socio-technical systems — An analysis of transformations in the Australian urban water sector', *Technological forecasting and social change*. North-Holland, 103, pp. 298–312. doi: 10.1016/J.TECHFORE.2015.11.023.

Geels, F. W. (2004) 'From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory', *Research policy*, 33(6-7), pp. 897–920. doi: 10.1016/j.respol.2004.01.015.

Geels, F. W. and Schot, J. (2007) 'Typology of sociotechnical transition pathways', *Research Policy*, pp. 399–417. doi: 10.1016/j.respol.2007.01.003.

Gleick, P. H. (1994) 'Water and Energy', *Annual Review of Energy and the Environment*. Annual Reviews, 19(1), pp. 267–299. doi: 10.1146/annurev.eg.19.110194.001411.

Golzar, F. and Silveira, S. (2020) 'Impact of improved heat recovery in buildings on the performance of centralized energy recovery – a case study of Stockholm'.

Graham, S. and Marvin, S. (2001) *Splintering Urbanism: Networked Infrastructures, Technological Mobilities, and the Urban Condition*. London & New York: Routledge. doi: 10.1353/tech.2002.0124.

Green, J. and Newman, P. (2017) 'Citizen utilities: The emerging power paradigm', *Energy Policy*, pp. 283–293. doi: 10.1016/j.enpol.2017.02.004.

Hansen, U. E. *et al.* (2018) 'Sustainability transitions in developing countries: Stocktaking, new contributions and a research agenda', *Environmental science & policy*. Elsevier, 84, pp. 198–203. doi: 10.1016/J.ENVSCI.2017.11.009.

Hillman, K. *et al.* (2011) 'Fostering sustainable technologies: a framework for analysing the governance of innovation systems', *Science & public policy*. Narnia, 38(5), pp. 403–415. doi: 10.3152/030234211X12960315267499.

Högselius, P., Kaijser, A. and van der Vleuten, E. (2015) *Europe's Infrastructure Transition: Economy, War, Nature*. Palgrave Macmillan UK. Available at: https://play.google.com/store/books/details?id=ZGakCgAAQBAJ.

Hughes, T. P. (1993) *Networks of Power: Electrification in Western Society, 1880-1930*. JHU Press. Available at: https://play.google.com/store/books/details?id=g07Q9M4agp4C.

International Energy Agency and The United Nations Environment Programme (2018) '2018 Global Status Report: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector'. International Energy Agency and the United Nations Environment Programme Paris.

Kanger, L. and Schot, J. (2018) 'Deep transitions: Theorizing the long-term patterns of socio-technical change', *Environmental Innovation and Societal Transitions*. Elsevier, (September 2017), pp. 0–1. doi: 10.1016/j.eist.2018.07.006.

Kretschmer, F., Simperler, L. and Ertl, T. (2016) 'Analysing wastewater temperature development in a sewer system as a basis for the evaluation of wastewater heat recovery potentials', *Energy and Buildings*, 128, pp. 639–648. doi: 10.1016/j.enbuild.2016.07.024.

Lawhon, M. and Murphy, J. T. (2012) 'Socio-technical regimes and sustainability transitions : Insights from political ecology', *Progress in human geography*. SAGE Publications Ltd, 36(3), pp. 354–378. doi: 10.1177/0309132511427960.

Lee, D. and Hess, D. J. (2019) 'Incumbent resistance and the solar transition: Changing opportunity structures and framing strategies', *Environmental Innovation and Societal Transitions*, 33, pp. 183–195. doi: 10.1016/j.eist.2019.05.005.

Lu, W. and Leung, A. Y. T. (2003) 'A preliminary study on potential of developing shower/laundry wastewater reclamation and reuse system', *Chemosphere*. Elsevier, 52(9), pp. 1451–1459. doi: 10.1016/S0045-6535(03)00482-X.

Monstadt, J. and Schramm, S. (2017) 'Toward The Networked City? Translating Technological ideals and Planning Models in Water and Sanitation Systems in Dar es Salaam', *International journal of urban and regional research*, 41(1), pp. 104–125. doi: 10.1111/1468-2427.12436.

Nygren, J. and Hjort, P. (2020) *Systemuppbyggnad och entreprenörskap från grunden : Fallstudie: "off- grid" vatten- och avloppslösning på Värmdö*. diva-portal.org. Available at: https://www.diva-portal.org/smash/record.jsf?pid=diva2:1446851 (Accessed: 7 July 2020).

Rodríguez-Pose, A., Crescenzi, R. and Di Cataldo, M. (2018) 'Institutions and the Thirst for "Prestige" Transport Infrastructure', in Glückler, J., Suddaby, R., and Lenz, R. (eds) *Knowledge and Institutions*. Cham: Springer International Publishing, pp. 227–246. doi: 10.1007/978-3-319-75328-7_11.

Silver, J. (2015) 'Disrupted Infrastructures: An Urban Political Ecology of Interrupted Electricity in Accra', *International journal of urban and regional research*, 39(5), pp. 984–1003. doi: 10.1111/1468-2427.12317.

Sitzenfrei, R., Hillebrand, S. and Rauch, W. (2017) ‘Investigating the interactions of decentralized and centralized wastewater heat recovery systems’, *Water science and technology: a journal of the International Association on Water Pollution Research*, 75(5-6), pp. 1243–1250. doi: 10.2166/wst.2016.598.

Stirling, A. (2014) ‘Transforming power: Social science and the politics of energy choices’, *Energy Research & Social Science*. Elsevier Ltd., pp. 1–13. doi: 10.1016/j.erss.2014.02.001.

Summerton, J. (1994) *Changing large technical systems*. Westview press Boulder, CO. Available at: https://pdfs.semanticscholar.org/8a59/931b9a0c8757c08d951b4ebf22e053e1fcc3.pdf.

The Economist (2017) *A world turned upside down*, *The Economist*. Available at: https://www.economist.com/briefing/2017/02/25/a-world-turned-upside-down (Accessed: 12 June 2020).

Tongur, S. and Engwall, M. (2014) ‘The business model dilemma of technology shifts’, *Technovation*, 34(9), pp. 525–535. doi: 10.1016/j.technovation.2014.02.006.

UN Water (2018) *Sustainable Development Goal 6 synthesis report on water and sanitation*.

Van der Vleuten, E. (2019) ‘Radical change and deep transitions: Lessons from Europe’s infrastructure transition 1815--2015’, *Environmental Innovation and Societal Transitions*. Elsevier, 32, pp. 22–32. Available at: https://www.sciencedirect.com/science/article/pii/S2210422417301491.

Wallin, J., Knutsson, J. and Karpouzoglou, T. (2020) ‘A multi-disciplinary analysis of the potential for building level graywater reutilization for hygiene purposes’.

van Welie, M. J., Truffer, B. and Gebauer, H. (2019) ‘Innovation challenges of utilities in informal settlements : Combining a capabilities and regime perspective’, *Environmental Innovation and Societal Transitions*. Elsevier, (June 2018), pp. 0–1. doi: 10.1016/j.eist.2019.03.006.

Yin, R. K. (2012) *Applications of Case Study Research*. SAGE Publications. Available at: https://play.google.com/store/books/details?id=-1Y2J0sFaWgC.