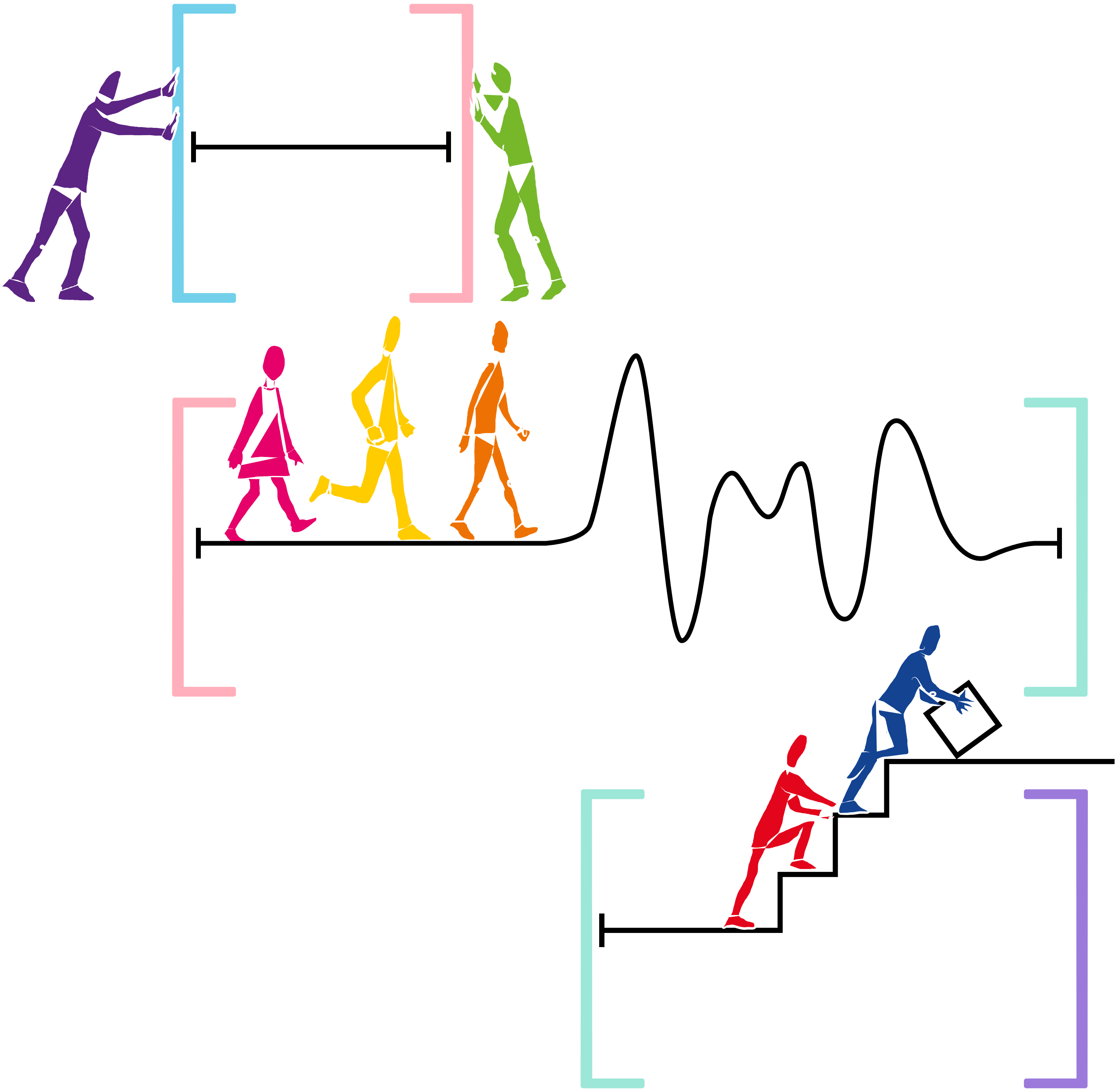

CONTROL, CHANGE AND CAPACITY-BUILDING IN ENERGY SYSTEMS

SHAPE ENERGY Research Design Challenge

SHAPE ENERGY

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Editors

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Executive Summary

The Research Design Challenge set out to showcase how different Social Sciences and Humanities (SSH) disciplines approach three scientific energy problems, namely control, change, and capacity-building in energy systems. This design challenge is an attempt to foster interdisciplinary collaboration in the energy-SSH community throughout Europe. 31 researchers based in 14 different European countries and representing 16 SSH disciplines came together through SHAPE ENERGY funding and developed 13 research designs according to the challenges defined. These challenges serve as a framework to order the contributions along three dimensions, which we call *reference problems*:

- Challenge A concerns the problem of *control* with increasing system complexity, because more heterogeneous elements and varying interrelations between these elements can lead to emergent behaviour of energy systems. Three author teams discuss organizational solutions related to aspects of social control such as governance, political autonomy or complex system intervention;
- Challenge B describes the problem of *change* despite the need for stability because in the destabilization of institutions, an overall loss of orientation should not occur, while simultaneously unlearning knowledge and deviating from routines is mandatory. The conditions and possibilities of social innovations are introduced by six papers, relating to energy pioneers, lived experience, electric mobility, values and building energy use;
- In Challenge C, we encounter the problem of *capacity-building* due to the increasing discrepancy between 'simple' interfaces and complicated technological realities in the background. Four papers focus on social mechanisms and innovations that mobilize human behaviour and allow to absorb uncertainty in order to remain actionable, e.g. on markets, in local communities or as building occupants.

These reference problems provided integration potential by channelling researchers' attention towards the problem at hand, going beyond their disciplinary academic definitions and comprehensions. This is illustrated by many researcher teams with different disciplinary backgrounds who have engaged with common, unified approaches without drawing lines between the disciplines involved. Thus, we conclude a successful first application of this concept, which hopefully finds imitators and contributes to author team follow-ups and SSH community resonance.

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INTRODUCTION

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Original call for abstracts (launched August 2017)

European and worldwide energy policy and research are largely influenced by knowledge and disciplines from Science, Technology, Engineering and Mathematics (STEM). Yet the challenges energy transitions entail concern social patterns as well, like individual or organisational behaviour and their management. These issues are covered by energy-related Social Sciences and Humanities (energy-SSH) disciplines. In fact, according to the European Commission (EC) Horizon2020 work programme on energy, knowledge from numerous fields of research is necessary to realise the ambitious goals of energy transitions concerning emissions reductions, renewable energy shares and the concomitant changes in social organisation. In what ways different energy-SSH disciplines design a research challenge related to overarching energy research problems (see next section) is the objective of this call. Ultimately, it aims at inferring consequences for multi- and interdisciplinary energy-SSH research that serves both the academic and energy policy community.

Therefore, the EU-Project 'SHAPE ENERGY[1]', represented herein by the partner institution Karlsruhe Institute of Technology (KIT), Institute for Technology Assessment and Systems Analysis (ITAS), invites European SSH researchers to take part in our 'Research Design Challenge'. This challenge contains three sub-challenges framed as social science research problems on energy relating to *control, change and capacity-building* in energy systems (see below). The Research Design Challenge is an attempt to deepen our understanding of interdisciplinarity by analysing how different social sciences and humanities disciplines research the same scientific problem. Across multiple SSH disciplines, up to 15 teams of at least 2 researchers from at least 2 European countries will be selected and **funded with up to 2.500 Euros** to foster collaboration (funded to cover travel to meet up). In the wake of current EC initiatives, applications to this call for abstracts could be, among others, appealing for researchers who plan on follow-up applications with H2020 or EU-related programmes like COST or Marie Skłodowska-Curie, for instance. We seek your application for an eventual 3.000-4.000 words paper on one of these challenges if you are researching in one of the following SSH disciplines: *Business; Communication Studies; Criminology; Demography; Development; Economics; Environmental social science; Education; Gender; History; Human geography; Law; Linguistics/languages; Philosophy; Planning (architecture); Politics; Psychology; Science/tech studies; Sociology; Social anthropology; Social innovation; Social policy; Theology. However we note that it is fine to include SSH disciplines from outside this list.*

The challenge(s)

For the Research Design Challenge, we are interested in your theories, methods and approaches to an energy related research problem from your disciplinary point of view (see list above to qualify). The prerequisite is that you find at least one more partner (individual[s] from European academic institution[s]) from a different European country (**EU member states and associated countries[2]**) to collaborate on the challenge. The challenge itself is kept relatively general in order for many potential researches being able to connect to it. They relate to the overarching research problems of control, change and capacity-building[3] in energy systems from a social science and humanities perspective. Please consider the following three sub-challenges to relate to:

Challenge A: It is argued by many STEM and energy-SSH scholars alike that future energy systems will increase in complexity, due to larger degrees of decentralisation and the growing amount of actors and technical components in the grid. Against this background, it will be a challenge for system operators and

1 A €2m EU Horizon 2020 funded (2017-2019) Social sciences and Humanities for Advancing Policy in European ENERGY (SHAPE ENERGY) Platform.

2 Albania, Armenia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Faroe Islands, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Montenegro, The Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine, the United Kingdom, and the former Yugoslav Republic of Macedonia.

3 **This concept and the concomitant challenges are based on:** Büscher, C. and Sumpf, P., 2015. "Trust" and "confidence" as socio-technical problems in the transformation of energy systems. Energy, Sustainability and Society, 5(34), pp. 1-13.

supervisors in numerous fields to *remain in control* of what happens in the system, i.e. control of technical processes (safety, security of supply, load management etc.) as well as social processes (e.g. control of market developments, control of electricity prices, control of smart grid data etc.). From your (disciplinary) point of view, how would you approach the (research and real-world) *problem of control* in future energy systems? What theories and methods would you apply to research this problem? What approaches would you suggest to act upon this problem?

Challenge B: During the current energy transitions in Europe and beyond, we see that institutional change and learning are crucial prerequisites in order to achieve a more efficient and sustainable system, i.e. changing markets with new challenger actors, learning utilities extending their portfolios, changing political subsidies policies etc. In this connection, energy-SSH discussions circle around degrees and relations of *stability and change*, given that some elements in the system must remain stable to perform system functions reliably during the transition with regard to current sustainment of operation (security of supply today, safety today, price stability today etc.). In other words, you can't change everything at once. This paradigm is often associated with the notion of (societal) experimentation, where certain islands of innovation are being tested and set variant while others remain stable to deliver familiar output, e.g. incumbent actors trying to hold on to the status quo while experimental niches try to foster innovation as quickly as possible. This balance between stability and change in the system for a transition to be successfully implemented is a repeated point of reference for energy-SSH. From your (disciplinary) point of view, how would you approach the (research and real-world) problem of *stability and change* toward future energy systems? What theories and methods would you apply to research this problem? What approaches would you suggest to act upon this problem?

Challenge C: In the past, the energy system was said to be existing only 'behind the power outlet'. The consumer was usually not considered an active part of the system, but rather the passive receptor of a service, or the 'end-user'. This pattern is currently, and more so in the future, under transition along energy system innovation. 'Prosumers' and 'energy citizens', designed as active system components, are desired as roles for average consumers, helping the grid´s stability as demand-side management resources due to intermittent renewable energy sources, as well as creating new business opportunities for consumers and European economies alike. The underlying prerogative for this kind of development clearly is the *mobilisation of action capacity* (i.e. the ability to act in the face of uncertainty) among both private and commercial consumers, who are expected to more actively participate in load shifting operations to make the 'smart grid' work. From your (disciplinary) point of view, how would you approach the (research and real-world) problem of *capacity-building, i.e. fostering the actions necessary* to realise active consumer involvement? What theories and methods would you apply to research this problem? What approaches would you suggest to act upon this problem?

The research design challenge: Output, background and paper allocation

The SHAPE ENERGY Research Design Challenge (RDC) embarked from the assumption to contribute to the integration of different energy-SSH disciplines, and potentially technical disciplines, throughout Europe. In the original SHAPE ENERGY proposal, we promised to set *the parameters for the research design challenge, which aims to showcase, across 15 SSH disciplines, how each would develop different methodologies for exploring a particular energy challenge and highlight possible policy mechanisms these could feed into.* With this report, we are able to present the following output: 31 researchers based in 14 different European countries, representing 16 SSH and five more technical disciplines[4], came together through SHAPE ENERGY funding and developed 13 research designs according to the set challenges. These challenges serve but a framing purpose to order the contributions along three dimensions, involving the research problems of control, stability and change, as well as capacity-building in energy systems. This research design challenge is an

4 Design, Science and Technology Studies (STS), Future Studies, Scenario Planning, Economics, Business, Politics, Law, Built Environment, Sociology, Social Anthropology, Engineering & Sciences, Human Geography, Philosophy, Economic Geography, Technology Assessment, Environmental Management, Psychology, Fiction, Ethnography, Planning (architecture).

attempt to foster *interdisciplinary collaboration* in the European (SSH) energy community, a) through direct funding and bringing together of researchers, b) through setting examples of interdisciplinary approaches and topics by authors, and c) through the structured way of aligning the contributions to overarching research problems (challenges A-C), creating a holistic and non-arbitrary way of looking at pressing energy-SSH questions.

In general, integration of research is frequently achieved by targeting a specific, often limited object of scrutiny. For the energy system (generation, transportation, distribution, storage and consumption), many researchers in interdisciplinary contexts agree on the label of “socio-technical systems” (Geels, 2004; Verbong and Geels, 2007; Sovacool and Hess, 2017) as smallest common denominator. In the energy system ‘it is not all about physics’, societal norms and values are, moreover, relevant. Normative criteria like reliability, safety, affordability and sustainability of energy have to be considered. However, even if this heterogeneity in relevant aspects is acknowledged, it is still a huge challenge to integrate the different technical, economic and social perspectives on the energy system. Moreover, while norms are political goals, they are not, as yet, scientific or scholarly problems. Academia needs to transform these norms into scientific problems which generally concern complicated or complex systems, e.g. technical systems (like power plants, grids, algorithms), climate systems, or social systems (such as organizations or groups). This is where many attempts of interdisciplinary work tend to get lost in endless debates about system definitions. Academic observers select elements (technical and social) and draw system boundaries, although there is rarely a common understanding to be found between different disciplines because these have their own internal history of dealing with the issues at hand.

This is where we set a turning point and created three challenges that embody *research problems* for multiple disciplines to connect to rather than dividing research up into technical, social, environmental, political issues etc. Decomposing the system into separate pieces for single disciplines to work on and then putting the results won in isolated examinations back together as one big final piece of evidence is a common approach in interdisciplinary research alliances. Our understanding, on the contrary, relates to the analysis of problems and their solutions, from a historical-evolutionary point of view (Hughes, 1987; Luhmann, 1994). The (again: technical, social, environmental, political) problems that energy transitions produce are countered by experts and incumbent actors with solutions, on an ongoing basis. One example is the promotion of renewable energy sources (RES) as a technical solution to the problem of fossil-fuel based energy sources causing negative CO_2 balances. However, every new (technological) solution creates new problems. The introduction and implementation of RES during the last decades has occurred to replace carbon dependent energy provision. That fact in itself has created new challenges, notably, for storage and transportation of electricity, for the coordination of various economic, political or academic actors, as well as for legislative and administrative decision-making regarding the installation of corresponding infrastructures (power plants, physical networks).

As a consequence, we relate to various research - or *reference* - problems of interdisciplinary research in this design challenge collection. These reference problems - control, change and capacity-building - need to be sufficiently abstract in order to be attractive for multiple (technical and social) academic disciplines to relate to. They embody both social and technical problems in the energy system, which need constant attention, because they cannot be solved for good. These types of problems have to be answered in the present, on an ongoing basis, to sustain current operation and for the future to achieve sustainability of energy supply. In order to give an impression, if only briefly, about the nature of the reference problems of control, change and capacity-building, we took inspiration from research branches such as Large Technical Systems-Research (LTS), Innovation and Transition Research or Social Systems Research.

While these three approaches all refer to the relationship between social and technical realities, they emphasize different problems and use different theories and methods. Firstly, a multi-faceted picture of the development and *control of large, complex infrastructures* is generated in research on LTS, pertaining to our challenge A. Secondly, the *conditions of change in fairly stable technological domains* are discussed in research on innovations and transitions, constituting what we name challenge B. Finally, functional problems of *capacity-building* in the face of opaqueness and uncertainty in constantly evolving socio-technical constellations are analysed in research on social systems, which we frame as challenge C. In the following, we sketch out these three research fields briefly to provide the underpinnings for choosing the three reference problems for this research design challenge. Subsequently, we introduce the contributing papers pertaining to the respective sections.

Research on LTS: Development and control of large, complex infrastructures (Challenge A)

Previous research on the emergence of socio-technical systems (Hughes, 1983; 1987), on the governance of large technical systems (Mayntz, 2009, 2004), or on socio-technical infrastructure systems (Edwards, 2004; Edwards et al., 2007; Jackson et al., 2007) analyses the emergent qualities of entities wherein social and technical elements interrelate. These scholars conceive of socio-technical systems as open systems or networks of heterogeneous elements, held together by a purpose: that of providing energy, transportation, water, or world wide data exchange. Their research assumes that technical operations and social actions are *functionally complementary* and, consequently, focuses on antagonistic developments, stress, or breaches. Usually one finds exogenous (environmental) or endogenous (systemic) factors triggering changes of the system's characteristics, which then influence the quality of the infrastructure service (Künneke, 2008). This makes future states and/or behaviour of systems harder to predict, leading to problems of *indeterminateness*.

Concepts of socio-technical systems highlight the manifold relations between their heterogeneous elements, indicating a high level of "organized complexity" (La Porte, 2015). In energy transitions, complexity is all-embracing: Different types of power plants (for conventional and renewable energy sources) are connected to the network through transmission lines, distribution networks and smart devices. Moreover, different actors, such as companies, administrations, communities, groups and private persons, are interrelated through rules, contracts, markets and regulations. Yet *"in general infrastructures are not systems. Instead, they are networks or webs that enable locally controlled and maintained systems to interoperate more or less seamlessly"* (Edwards et al., 2007, p.12). *Control* of such interwoven networks from both technical and social viewpoints, as set out in challenge A, turns into a vital research component.

Challenge A: Paper introductions

In line with the original call for abstracts (CfA) and following the description provided above, we have aligned three RDC contributions with the dimension of 'control'. The control dimension in energy research is more or less dominated by technical and economic approaches, and thus constitutes arguably the smallest section of the RDC. Still, we have managed to attract valuable social science based research designs in this section, comprising issues of *social control* in complex socio-technical systems such as governance and energy justice.

Our first paper by Alicia Smedberg and Anne Light on 'Autonomy and control in Orkney: An inquiry into the social benefits of community wind energy' embodies the control variable in terms of political control of the Scottish energy sector. Orkney, as a remote island of Scotland, is described in that its "*[...] energy management was made difficult by a lack of control over the network into which the energy flows*" (p. 22). The authors argue that feed-In tariffs by the UK government to stimulate RES development in Orkney were created, yet "*[...]Holyrood still has no control over energy production and consumption in Scotland*". In the end, "*[...] the incentive behind the hydrogen projects is not to create a viable business so much as to build resilience and autonomy in the island communities*" (both p. 24). So RES schemes, in the authors' view, serve primarily as a means to gain more control in a remote island community that strives for self-determination in energy policy application.

Subsequently, Ethemcan Turhan, Alevgul Şorman and Katarina Larsen present an approach toward 'Reconciling qualitative and quantitative storytelling in just energy decision making: A research design challenge contribution'. Their take on control incorporates control of unintended side effects of energy transitions, that, according to their view, unfold in a "*mess first, fix later*" (p. 28) way. In particular, their perspective relates to controlling energy transitions' effects on the socially underprivileged. The authors argue that existing narratives and procedures of decision making do not necessarily consider all relevant knowledge available to reduce social costs of transitions, and that reflection on this in the community is rather low. Their proposition entails a reconciliation of quantitative and qualitative approaches in the field to come to improved decision-making capacities in considering the uncovered weaknesses.

Section A is concluded by Pierre Wokuri and Viera Pechancová, who study 'Islands of innovation in the UK and the Czech Republic'. Their research design encompasses a comparison between two local energy initiatives in the Czech Republic and one in the UK. Through semi-structured interviews with representatives from the projects, they were able to examine "*forms of collaborations, stakeholder roles, success factors and barriers in the community energy projects*" (p. 36). They offer perspectives on similarities and differences between them and a final account of conditions for implementing such projects, which they tie to their governing modes and funding schemes as a means to exert social control.

Research on innovations and transitions: Conditions of change in relatively stable technological domains (Challenge B)

Several concepts concerned with socio-technical systems accord an important role to institutions and to processes of institutionalization (Fuenfschilling and Truffer, 2014; Smith, Stirling and Berkhout, 2005). Recently, transition research has drawn on the structural and institutional features of socio-technical systems with crucial infrastructure (such as energy, water, rail roads and telecommunications). A very prominent feature of transition research is the analysis of the relations between *stability* (configuration, structure and institution) and *change* (co-evolution, structuration and institutionalization). Within the framework of transition research, the Multi-Level Perspective (MLP) addresses socio-technical transitions as a function of stability and change caused on three analytically distinct levels: regime, niche and landscape (Geels, 2004). The regime is the dominant structure within a socio-technical system; in a regime, a multitude of actors and organizations is tightly interwoven into a network of mutual dependencies held together through formal and informal relations, e.g. through contracts or trust. The regime determines social relations by virtue of institutionalized expectations, such as cognitive rules of scientific observation, agreed upon knowledge, established technical paradigms and belief systems (Geels, 2004, p. 910; Smith, Stirling and Berkhout, 2005, p. 1508). In this sense, stable structures and institutions are necessary features of social life, providing orientation and enabling action.

The energy infrastructure in many European countries is a highly regulated complex, with strongly institutionalized networks of incumbent actors, but it is now in flux because of energy transition initiatives. In countries with very ambitious RES goals, like Germany, the transformation is executed as a real-time experiment of socio-technical nature, comprising experiments with technical (energy sources, smart devices) and social aspects (regulation, consumer behaviour). "*Research on energy has increasingly turned society into a laboratory -- one in which the energy user and non-scientist can potentially play an active part in the experiment*" (Gross and Mautz, 2015, p. 140). To govern this transformation, one needs a balance between tight experiment-reality couplings (which enable innovative, realistic, close-to-the-market benefits) and loose couplings, which disturb the system's operation as little as possible. To foster social change, one needs stable generalized expectations to sustain action orientation and less 'resilient' institutions to increase learning capacities (Strunz, 2014). The various technical and organizational changes linked to the energy transition require somewhat synchronized learning processes of rather different sets of actors. To enable a successful transition, learning capacities are a key requirement in the context of processes of institutionalization and de-institutionalization - and learning takes time. Nonetheless, due to the inevitable non-knowledge about the success of the energy system transformation, the public may be opposed to a learning experience, and such opposition would, presumably, prevent their active involvement. Therefore, the obvious need for change in any kind of transition is accompanied by the resilience of institutions that stems from their function of providing stable service operations.

Challenge B: Paper introductions

The second section of this collection addresses the balance between stability and change in energy systems. This section concentrates the largest amount of papers (six), which is congruent with our observation of the current SSH energy research community in focusing on transition and innovation research (Büscher and Sumpf, 2017). Section B commences with a contribution by Kat Buchmann, Shiri Heffer and Yael Parag. Their paper looks at ‘Energy pioneers: Energy start-ups, ecovillages in Israel and Germany’, thus targeting two important actors in energy transitions. The authors present a brief historical account of ecovillage development in both Israel and Germany, before characterizing them in their function as ‘pioneers of change’. Between radicalism and conformity, in alignment with MLP descriptions of regime vs. niche, both ecovillages and energy start-ups are described in their roles as bringing change to the energy community, with distinct differences between Israel and Germany. The work is based on 14 semi-structured interviews with start-ups, ecovillages and government agencies.

Mary Greene and Anne Schiffer, in subsequence, provide us with an account on ‘Learning from past and current energy transitions to build sustainable and resilient energy futures: Lessons from Ireland and The Gambia’. While the authors acknowledge that there is research available “*from the lived everyday experience of energy to the broader spatial and institutional aspects of energy systems change*” (p. 58), they diagnose that “*comparatively little research work compares the lived experiences of energy systems change of industrialized countries with developing nations*” (Ibid.). In what follows, they unfold an empirically driven observation of contextual factors shaping energy behaviours in an industrialized (Ireland) and a developing nation (The Gambia), drawing on an analysis of 26 semi-structured interviews with people in both countries.

By ‘Envisaging the unintended socio-technical consequences of a transition from fossil fuel-based to electric mobility’, Aleksandra Lis, Aleksandra Wagner, Franco Ruzzenenti and Hans Jakob Walnum examine two major questions: “*What unintended socio-technical consequences might result from a transition from fossil fuel-based to electric mobility, and how to investigate them?*” (p. 68). Their perspective on electric mobility is directed at rebound effects like increased (electric) car ownership (shown in the case of Norway) or rising needs of electricity to power BEVs, which does not contribute to CO_2 reductions in the Polish case because the country heavily relies on coal-powered electricity generation. These conflicts of interest between new technological paradigms, climate change mitigation and behavioural consumer adaptations are uncovered through document study and theoretical considerations. The latter are supposed to help find ways to better analyse and visualize unintended side effects of major technology programmes like electric mobility, feeding into new SSH approaches in the field.

Carolin Märker and Christine Milchram provide an insight into stability and change in energy systems relating to ‘The role of values in analysing energy systems: Insights from moral philosophy, institutional economics and sociology’. Their hypothesis is: “*The energy transition [therefore] requires an institutional analysis that is capable of revealing the normative reasons behind institutional changes. An analysis of values can provide insights into these reasons because values are relatively stable underlying normative guiding principles for changes in a society*” (p. 78). The authors select the ‘Institutional Analysis and Development’ (IAD) framework to undertake this endeavour, and enrich it with a self-designed value perspective. Informed by moral philosophy, institutional economics and social psychology/sociology, they demonstrate the role of values as drivers of actions and their evaluation by both (energy) actors themselves and their social environment and propose framework application in both research and policy making.

‘Feeding back or feeding forward? A new lens into building energy use’ is the title of the fifth contribution in Section B, written by Sonja Oliveira and Magda Baborska-Narozny. The authors state that “*Building performance evaluations of both existing and new buildings across the EU have tended to reveal the at times vast difference between the predicted and actual energy use, often referred to as the performance gap*” (p. 89). This, according to the authors, is partly due to little developed means of feedback collection and evaluation in the built environment community, often relying on procedures like physical monitoring or occupancy satisfaction questionnaires only. Another aspect they uncover is that improvement is regularly seen in further application of measurement concepts, instead of thinking about qualitative change: “*The use of theoretical tools in the field of built environment research overall is still developing and largely overlooked*” (p. 90). Based on a workshop with participants from disciplines such as sociology, environmental science, sustainability consultancy, energy behaviour and engineering, the authors present pathways out of this situation, including 'broken feedback loops' between design, construction and use phases.

In a final contribution to Section B, Jens Schippl and Timo von Wirth engage in research 'Towards a stronger integration of spatial perspectives into research on socio-technical transitions: Case studies in the Swiss energy sector and the German transport sector'. In close alignment with MLP categories, they emphasize that the transport 'regime' in Germany is not homogenous and thus reacts differently regarding electric car introduction in urban compared to rural areas. In particular, the authors showcase two general trends visible in German mobility sector currently: "*one pathway where BEVs [battery electric vehicles] are mainly adopted as second or third vehicles in households with more than two persons (mainly families) in less densified areas, and a second one where BEVs are mainly embedded in car-sharing concepts in larger urban agglomerations*" (p. 98). Furthermore, the spatial dimension of an early diffusion of decentralized energy systems in Switzerland is presented as a second case study. Their final research question, complemented by some finer-grained trajectories, thus reads: "*To what extent do spatial settings cause or support convergence and differentiation in a socio-technical system such as the transport or the energy sector?*" (p. 100). The authors present first hints on research and policy consequences for a more spatially sensitive perspective in energy systems and its relation to stability and change.

Social systems research: The problem of capacity-building (Challenge C)

Sociological theories of social systems offer an interesting take on the ongoing technical development, i.e. digitalization, of the modern (energy) world. This research programme is based on the premise that there is a sharp distinction between technical operations and social operations[5]. The interrelations of the socio-technical should not be approached in terms of *functional equivalency* of socio-technical elements (like is often observable in LTS and/or transition research), but in terms of *structural coupling*. A structural coupling implies that while technology is subject of (or stimulates) social processes, it does not determine, overlie, or substitute social reality, because the types of operation are distinct: "*The technical network of energy flow is completely neutral to communication; in other words, information is produced outside the network and can only be disturbed by 'noise'. Causal relations between technological physics and communicated information are freed of overlap and take the form of structural coupling*" (Luhmann, 2012, p. 180). The case of ICT illustrates this structural coupling, for in spite of tremendous developments in electronic data processing (speed, volume and accessibility), social actors remain dependent on interpretation and choice in order to exploit the technological capacities. The information value of electronic data processing is determined by the processing of meaning by psychic or social systems (Baecker, 2011).

The structural coupling of technical and social realities produces both relief and new forms of stress. Our example of the energy system illustrates this with the operation of a power grid. Operators observe models of the physical network displayed on large screens. Symbols and signals have to be brought in relation to the real-world state of the grid, which is not assessable via immediate inspection. The relation between the 'flat' screen of the model and the 'deep' and complicated structure of the system behind the model simultaneously fosters both, transparency and opaqueness. The computer model provides data, however, merely possessing the data does not free from the need of interpretation and decision making. The interpretation of the data is only possible with expert knowledge. Operators who control critical infrastructure are particularly liable and therefore strongly perceive contingency (possible failures), experience uncertainty (lack of confidence in existing information (Brunsson, 2000, p. 39) and risk (high stakes). Unless uncertainty is absorbed by social mechanisms like trust, distrust and confidence, the capacity to act cannot be sustained. Therefore, capacity-building has to be sustained in energy transitions, despite the overwhelming opaqueness that accompanies the increasingly complex, digitized system which is operating in real time (Pasquale, 2015).

5 We acknowledge that some sociological theories, STS theories in particular, assume an overlapping occurrence of technology and social reality (Latour, 2007). We do not ignore this fact, yet concentrate on an underestimated theory as a basis for Challenge C that we drew inspiration from. Nevertheless, other ways of reasoning are possible, and many contributing authors have picked up STS literature and refer to socio-material constellations in contrast to our proposition here. For more details on this discussion see Büscher and Sumpf, 2015.

The illustrated effects of uncertainty apply to actors on the operator level and, increasingly, to regular users of energy, in the role of producers, consumers or 'prosumers'. Their interaction with opaque technology relates to novel smart devices, and market experiences that require trust as an advance credit because outcomes of their actions depend on others and can only be evaluated ex post to decision making (Büscher and Sumpf, 2015). Against this background, the motivation of both consumers and organized grid actors to conform to external expectations and build up action capacities is a central SSH research problem.

Challenge C: Paper introductions

This section of the collection begins with a contribution by Nives Della Valle and Giacomo Poderi, who ask 'What works for consumer engagement in the energy transition: Experimenting with a behavioural-sociological approach'. Through combining the more rational choice oriented approaches of behavioural economics with sociological insights, they create a framework incorporating both individual as well as contextual factors of decision making. With the overarching goal of altering consumer behaviour in energy-related decision-making in an effective and socially compatible way, they arrive at proposing 'participatory energy budgeting' (PEB) as a solution, yet presenting amendments to the concept. PEB is basically understood as a process where the target group of interventions – consumers – determines self-defined energy savings goals, including "*the collective management of the energy savings that derive from improvements in energy behaviour*" (p. 107).

Michael Fell and Diana Neves, in a subsequent paper relating to capacity-building, discuss 'Islands in the city? Place attachment and participation in local and non-local peer-to-peer energy trading'. Peer-to-peer (P2P) energy markets are at the centre of this contribution, as one major component sought to include more and more producers, consumers and prosumers of energy in load shifting and energy trade. Drawing on workshops, survey experiments and energy system modeling in their proposed research design, the authors present a threefold methodology that would help examine place attachment and participation frames in relation to local and non-local P2P markets. Ultimately, two research questions are to be answered by the proposed design: "*How does willingness to participate in P2P energy trading differ between local and non-local markets, and what affects this? Which might be the impact that P2P markets have in the local grid network management, when not exclusively managed for local grid benefits*?" (p. 115)

Thirdly, Marcel Schweiker and Gesche Huebner are focusing on capacity-building 'Beyond the average consumer: Exploring the potential to increase the activity of consumers in load-shifting behaviours by means of tailor-made solutions'. Their research design encompasses differential psychology and building science, which leads to an emphasis of individual user preferences and their interactions with building characteristics, all in relation to thermal comfort experiences. They present an attempt to deviate from 'average consumer' concepts in energy transitions, and argue that only through consideration of individual comfort perceptions will altering energy behaviour in line with current energy-savings goals be realistic. Their research design, consequently, aims at 'tailor-made solutions' to regulate space heating and cooling as resources with great load-shifting potential in energy systems. By combining methods from both psychology and building science, the authors develop their own conceptual framework as a basis for undertaking the proposed research design.

In a final contribution, Laura Watts, James Auger and Julian Hanna present 'The Newton Machine: Reconstrained design for energy infrastructure'. Situated on the Orkney Island of Eday, Scotland, they narrate how an electronic keyboard was gravity-powered with the help of the researchers conducting this design experiment on Eday. The authors, with the help of local community members, built this 'Newton Machine' with no pre-defined components, but mere locally available resources, both social and technical. This combination of human and material constituents is what they see as inherent to a Newton Machine, which they do provide a 'manifesto' for that includes characteristics it is supposed to entail. All in all, with their approach the authors try to pursue the following questions: "*What happens when domestic products do not end at the electrical cable and plug? How can we rethink the design process to incorporate what happens 'beyond the wall' to include the whole energy infrastructure and ecosystem? This approach aims to focus on the* *local and bespoke rather than global and generic.*" (p. 136). In wrapping up, they provide an instruction manual for replication of the experiment in different contexts.

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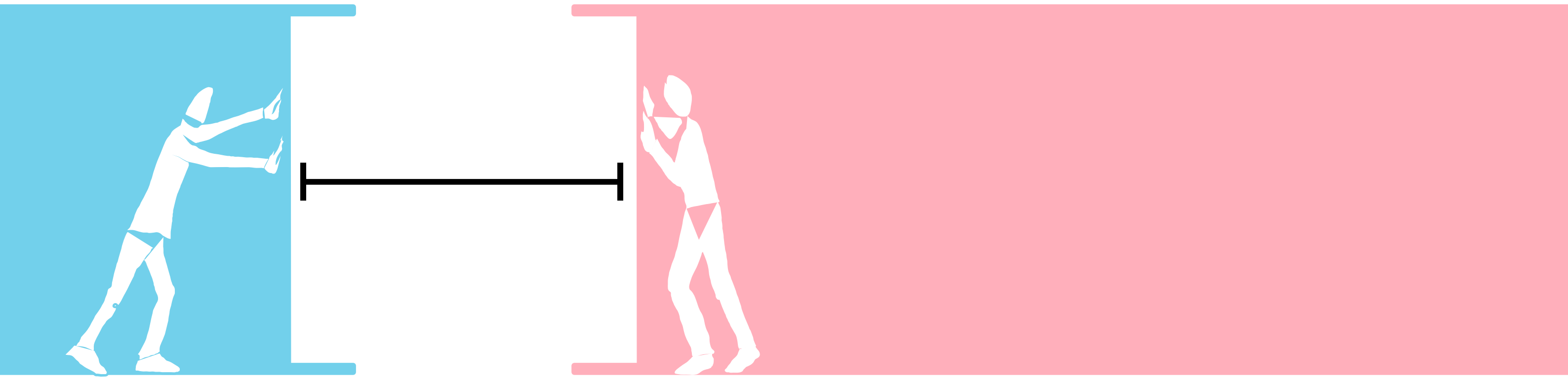

SECTION A
The challenge of 'Control' in energy systems

Smedberg, A.; Light, A.

Autonomy and control in Orkney:
An inquiry into the social benefits of community wind energy

Turhan, E.; Şorman, A. H.; Larsen, K.

Reconciling qualitative and quantitative storytelling in just energy decision making: A research design challenge contribution

Wokuri, P.; Pechancová, V.

Islands of innovation in the UK and the Czech Republic

Autonomy and control in Orkney: An inquiry into the social benefits of community wind energy

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1. Introduction

> "*In a wholesome society the different estates are stitched together in a single garment: the warmth and comfort and well-being of the people, a symbol too of their identity and their ethos. Their language, their work, their customs, all they think and do and say, decide the cut and style of the coat. [...] There was another coat; very precious and inviolable, their fathers and their grandfathers before them had imagined it and had given it to the looms of history [...]*" (Brown, 1972, pp. 76-77).

The poet George MacKay Brown (1921-1996) lived most of his life in Orkney and dedicated his life's work to the poetry he saw in an island shaped by its people and a people shaped by their island. In his book *An Orkney Tapestry*, originally published in 1969, he returns, time and again, to the analogy of the loom and the tapestry to describe the islands. As in the quote above, where he describes the "*different estates [...] stitched together in a single garment*", he also refers to the islands as a tapestry woven by history, people and things.

The Orkney with which we concern ourselves in this paper is still Brown's Orkney; it is still a place of almost indefinable integrity and its history still has an undeniable presence. In this paper, we look at the growth and impact of socio-material power infrastructures, in and around Orkney, over the past thirty years, based on two visits to observe, solicit diverse perspectives upon and study the development of "*community energy*" (Smith et al., 2016; Seyfang et al., 2013). We use onshore wind turbines as an inquiry into how the tapestry of Orkney is interwoven with the Scottish mainland, the UK and Westminster. By tracing the development of renewable energy here, we offer the reader an account of local control and agency, in response to the SHAPE ENERGY 'control' challenge.

In bringing a historical socio-technical inquiry to bear on energy production and local control, we draw attention, also, to the language of our account and, indeed, any account that deals with power supplies. The word 'power' comes to English from the Latin, via Old French, meaning 'ability to act or do'. 'Energy', 'agency' and 'control' also relate to the means to perform actions and alter states. In this account, we juxtapose the ethereality of electricity, with its *technical* power to enact change through chemistry in ways determined by physics, with the equally immaterial flows of power that arise in the *socio-technical* sphere of erecting wind turbines, seeing the history of control of energy in Orkney as a meeting – and intertwining – of these technical and socio-technical factors, playing through the material infrastructure of cables, turbines, batteries and the grid.

2. Background

Orkney was thrust out of the sea during the ice age, as glaciation pushed down the Scottish mainland, but that ice has melted and the archipelago is sinking. For 600 years, it was under Norwegian rule before being traded to the UK in the 15th century (Bambery, 2014).

The islands are bare of trees, surrounded by the Atlantic Ocean and the North Sea. They are a place of strong currents, fertile soil and gushing wind. Their permanent population is about 20,000.

Despite functioning as an outpost for two world wars and sitting at the heart of the oil industry boost in the 1970s, Orkney has long suffered for its remoteness. There is a shortage of work, an increasing generation gap and an ageing population, with many of Orkney's young leaving the islands to pursue higher education and work. The Scottish Government (2015) sees an acute need to introduce new industries to Orkney to boost its economy (Kerr, et al., 2014).

Further, the archipelago has one of the worst cases of fuel poverty in the UK (Hull and Milner, 2012). A high percentage, 68% in 2013, of the buildings on the islands are old and poorly insulated, causing them to consume more heat energy than necessary (Orkney Housing Association, 2015). Both energy prices and energy consumption are higher than the national average (Orkney Island Council, 2009; Orkney Island Council, 2015).

The publication of the Scottish Government's 2020 vision for renewable energy (2015) included a vision that energy generation should create new jobs and benefit national industry, as well as provide a more sustainable alternative to conventional energy generation. It is unfortunate for both Orkney and Scotland that the devolution of powers to the Scottish Government (ibid.) did not include responsibility for energy policy.

3. Disciplinary and conceptual framework

The two researchers brought together by this inquiry identify as design researchers, situated at the intersection of Participatory Design (e.g. Ehn, Hillgren and Björgvinsson, 2010; Light, 2010) and Science and Technology Studies (STS, e.g. Law, 2004). We are alive to the interplay of ambition and contingency and the social and material considerations that design entails. To this, we add a sensibility drawn from feminist studies (e.g. Haraway, 1988) as to the interpretive nature of accounts and account giving and the need to articulate viewpoints, both our own and others. Additionally, Actor-Network Theory (ANT) has informed our understanding of socio-material networks, actors and agency (Latour, 2005).

In tracing the network, or tapestry, of intertwined connections, we are not the first to explore mutual dependencies between things and people in the context of energy. For instance, Bennett, in her book *Vibrant Matter* (2010), uses an example of an energy grid blackout in North America. The network she presents in the story of why the system 'failed' is an assemblage including electricity, circuits, transmission lines, power plants, energy trading cooperations and consumers. Bennett's account raises, as she notes, a question about the agency of the agent. Likewise, we acknowledge a wide range of actors whose influence is hard to determine. The flux of the renewable energy projects in Orkney has been influenced by obsolete aircraft materials, grid ownership, legislation affecting Scottish autonomy and other unanticipated elements, as well as the people, history and economy of the islands. It is no easy task to see the complexity and avoid grand homogenizing narratives that allows us to make sense of the system (cf. Law, 2002). Building connections has been a crucial aspect of getting wind energy from wind; tracing these connections helps us demonstrate the complexity of the system, but also tell a story of interrelations.

4. Methodology

Our challenge is to present a meaningful narrative here, making certain relations stand out, yet without any claim of exclusive truth (Abbott, 2001). We do this through a series of simplifications, but include one section of (highly selective) accounting from interviews to give a sense of plural perspectives. Balancing these, we drew from multiple further sources in many forms: written, drawn, photographed, narrated, retold; some gathered through visits to the islands and others from secondary sources such as annual reports, minutes from meetings and publications. The methods developed in response to the material at hand (Lury and Wakeford, 2012). This includes how we (the two researchers) decided which parts of the story to tell, through further conversation over the notes of island interviews. We checked our account with the original interviewees, for accuracy and tact.

Drawing on Bang and Eriksen's (2014) model of the programmatic approach, we position our engagements with various historical materials in the centre – forming the core of our inquiry. The programme in our case holds the conceptual framework, which, in turn, is framed by the challenge. The narrative was developed alongside continuous comparisons between challenge and data. It has been, as George MacKay Brown might have put it, a weaving process.

The first visit to Orkney took place in the autumn of 2016 (Smedberg, 2017); the second in early 2018, both using interviews and observation as primary research methods. We learnt more of the details from traces in the form of planning documents, minutes from meetings, applications, proposals, newspaper reports, blogs, legislative documents, information sheets, reports and so on. Many of these documents are available online; others were obtained at the public library in Kirkwall or directly from Orkney Council. Although we consulted many sources, the list is far from exhaustive. It was sufficient, however, to give a sense of which suggestions, from which groups and individual actors, have been carried through and which dropped.

To complement this information, interviewees were selected on the basis of their relation to the renewable energy projects. The two iterations of our research allowed us to revisit interviewees over time, to capture not only their views and accounts, but also changes in their views.

5. A history of wind turbines

The first wind turbine was built in Costa Head, Orkney, as early as 1951. In the previous decade, the islands had served as a naval base for the British troops during WW2. A firm of Glasgow engineers, who had specialized in shipbuilding and marine engineering during the war, saw an opportunity to make use of the excess army material and constructed the first wind turbine in the UK ever to function with a grid connection. The materials they used to build it were not optimal, being originally designed for a different purpose, and the chosen site left the turbine overly exposed so the machine soon broke down[1] . But the experiment had nonetheless been a successful one, proving wind turbines were a viable instrument to generate electricity.

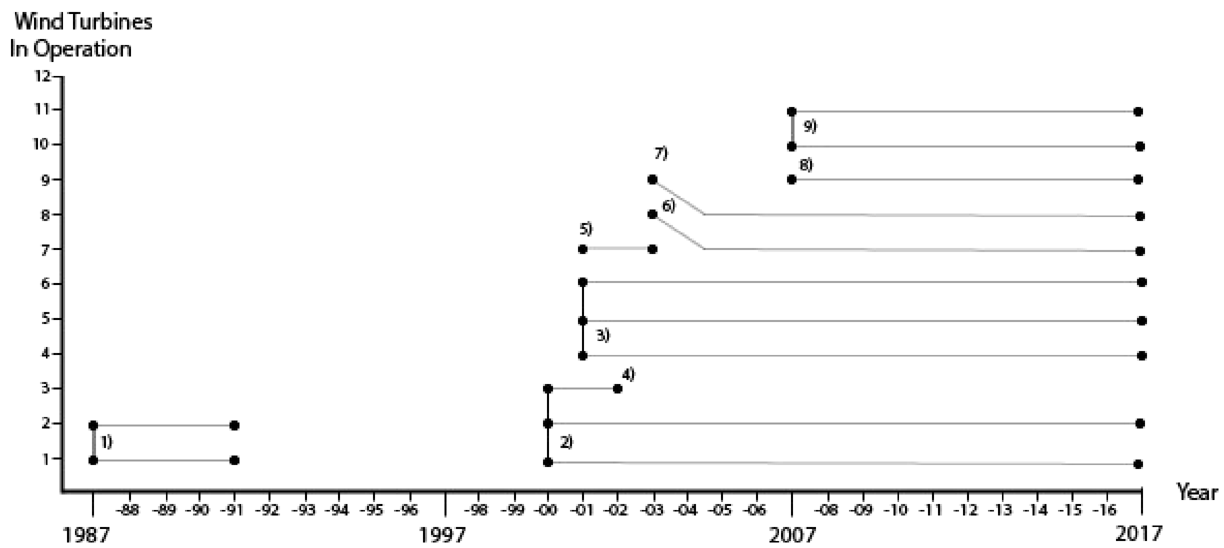

Figure 1 – Time of construction, and duration of wind farms in Orkney (Diagram: Alicia Smedberg)

In 1985, another group of engineers came to Orkney to test out the possibility of offshore wind energy. The UK was searching for new sources of both energy and income after the 1970s oil boom in Scotland; the islands were seen as generically "*offshore*" and a good site for the pioneering wind energy industry (Johnson et al., 2012). The next turbine, based at Burgar Hill, was upgraded continuously; the original blades of steel were replaced with more durable glass fibre epoxy and the machine was optimized for its particular setting. It stood for ten years while a medium-sized wind farm grew round it (see Figure 1). One of the engineers from this initiative made his home in Orkney and set up the company that now accounts for most of the major turbines on the islands.

In the period between 1985 and 2015, more than 500 wind turbines were built or installed on the islands, an ANM (Active Network Management system) smart grid was introduced and the connections between the mainland grid and Orkney were updated. After the 2003 Land Reform Act (The Scottish Parliament, 2003, asp 2) entitled smaller communities to register an interest in and buy land, some islanders used this to pursue joint energy ventures (Kerr, et al., 2014). The change in land rights not only made it easier to promote community-owned initiatives but potentially more lucrative (Kerr, 2006).

1 Gauld, R. (13 February 2018), Personal Interview.

6. Management

One challenge that emerged early was the relationship between the turbines and the grid. As well as the technical challenges of turbine maintenance, efficiency and lack of storage, energy management was made difficult by a lack of control over the network into which the energy flows. The UK national grid was privatized in 1990 (becoming National Grid plc). The grid on Orkney is part of the national grid and developments are constrained by its capacity on the islands, which is limited, and the need for all energy to be absorbed into National Grid's network.

But, beyond managing technical issues, Orcadians have also been heavily involved in controlling the local energy scene for profit. Key to this was the Feed-in Tariff (FiT), a payment made by the UK government to anyone generating electricity into the national grid through wind, solar or wave energy. The initiative was implemented in 2010 and ran until 2016. During this time, rates were episodically decreased, leaving generators with smaller payments until the initial scheme closed completely. (There is now a second FiT scheme in operation, but it is more restrictive and inapplicable to most wind projects in Orkney.)

Once wind farms were considered viable, aided by these payments, renewable initiatives on Orkney diversified into three forms of local enterprise: the commercial model based on community investment, mentioned above; a community-based charity; and individuals with micro-renewables (such as leased smaller domestic wind turbines placed on private farms – this last allowing landowners a degree of autonomy over their own energy consumption, but still requiring connection to the grid in the terms of the lease) (Kerr et al., 2017).

The management company, *Orkney Sustainable Energy*, was designed to fulfil multiple purposes – to secure the cost of building turbines, guarantee local investment and diversify into other parts of the north of Scotland for added security – and there were several different models of investment. In some cases (such as Burgar Hill) there are several different investment models within the same windfarm. The fundamental idea, however, rests upon sharing the cost of the project, affording (local) shareholders a say in the project and a cut of its profits. By investing, these actors shoulder part of the cost and give the project greater stability, enhanced by accepting investors from outside the community. It is a traditional shareholder model.

The wind turbines are bought by the community as a whole in the charity *Community Energy Scotland* and no individual investment is required by the local citizens. The energy produced by the turbines also goes into the national grid, and, till 2016, the FiT returned to the community. A tension in this model has been how to spend the money, which sits in an account waiting for use. There is also an unaddressed question as to who counts as the community that can make this decision. As there is only a trickle of people in and out of the islands, this is not yet a major concern. At time of writing, there are 6 projects supported by *Community Energy Scotland*, ranging from wave turbines to standalone wind turbines, to the Surf 'n' Turf scheme seeking to find new uses for energy generated by the islanders.

7. Two visits

As noted, the research here is based on visits to the islands as well as secondary research. The next section is an account drawn from observations and interviews (in 2016, months after the FiT scheme closed, and in 2018).

"The attitude to wind energy in Orkney in 2016 was one of general demoralization; with the subsidies taken away, it looked as if the wind industry would slowly die out. Without governmental support, there was great uncertainty and new projects were being put on hold. Speaking to local people, my questions about the future of wind energy were answered with solemn headshakes and shrugged shoulders[2]. The subject seemed unwelcome and unpleasant."[3]

2 Higgins, S. (13 February 2018), Personal Interview.

3 Smedberg, A. (February 2018), Field notes from visits.

"I returned in 2018 and, while no new governmental support had been issued in the 18 months since my last visit, there was something else growing in its stead. Finding people who were willing to speak to me about wind energy – past, present and future – was no longer such a challenge. In conversations with island residents, the discussion was now welcome. It might sway towards tales of bitterness over the lack of support but even this I found preferable to the ringing silence from my last visit. And, this time, there were also tales of new initiatives: 'If you are researching wind energy, you should look at Eday. [...] Have you heard what they did in Westray?[4]'"[5]

Renewable energy specialist Sandy Kerr, based at the Heriot-Watt University campus in Stromness, tells the story of how residents of the island of Westray used wind energy as political leverage. Westray was the first example of community-owned wind turbines in Orkney. Historically an affluent island, the changing fishing industry in the 1980s and population decline led the community to take action in the 1990s. They organized a conference in the local school, inviting people from the island council and Scottish and UK government agencies. "*They [island residents] didn't think they would actually turn up, but actually everybody turned up. They took the school, and they had different rooms for different issues, and in a way they captured the decision-makers there.*"[6] With the decision makers in place, and with the prospect of placing a turbine on the island as leverage, the islanders argued and won an elderly care home and a youth centre for the community. Kerr points to this as an inherently political move, illustrating the influence that wind turbines can afford Orkney's communities. It is a far cry from the more usual refrain about windfarms – where developers are often limited in their choice of sites to ensure that the turbines are "*kept out of view.*"[7]

Yet, with the closing FiT schemes, many of the doors opened by wind energy also shut. Richard Gauld, from *Orkney Sustainable Energy*, talking in 2018, spoke with the concern and disappointment heard on the first visit to Orkney: "*A good industry has been created over the past 20 years and it would be a shame to see that effort lost.*"[8] He points out that, while continuous upkeep can prolong the life of a wind turbine, they are not eternal and eventually there will be a need for sizeable investment.

And, meanwhile, local environmental researchers and motivated residents point to the frustration that the wind power makes no difference to the way the energy is consumed on the islands.

Ian Garman is the Innovation Development officer for *Community Energy Scotland*, attempting to find alternative routes to make island life sustainable. In his opinion, the challenge today is not building new wind turbines; it is optimizing the financial return to the communities using the resources already available. For example, the Eday wind turbine, built in 2010, faces challenges from the smart grid – regulate or shut down. "*It is not an ask. If you don't react the grid will protect itself by cutting you off. You don't know for how long, and perhaps most importantly what the compensation will be.*"[9] Ian lists some of the charity's speculative projects: data farms, bitcoin farming, medicinal marijuana, green-house agriculture, marine transport. It is investigating whether it can sell hydrogen as fuel to power ships. "*It is incredibly complicated to beat electricity curtailment by simply shipping electricity from place to place. Nobody suggested that this is a viable activity. Nobody is going to look at it and think that it is a business opportunity. [...] the greatest by-product here is resilience. These Community Trusts, fundamentally, they are about combatting depopulation.*"[10]

8. Discussion: Autonomy and control

Orkney has been a long-standing site of innovation, hosting its first experiments into renewable wind energy in the 1950s. Other ventures into renewable energy – wind, wave and tidal – have followed. The Orcadians' desire for autonomy appears in their search for the means to harness the wind as a beneficial resource for

4 Ford, R. (14 February 2018), Personal Interview.
5 Smedberg, A. (February 2018), Field notes from visits.
6 Kerr, S. (15 February 2018), Personal Interview.
7 Gauld, R. (13 February 2018), Personal Interview.
8 Ibid.
9 Garman, I. (14 February 2018), Personal Interview.
10 Ibid.

the community and convert it into either monetary profit or electricity. On an island with big energy costs, it is a cruel irony that all the energy they make must, so far, go straight into a grid that exports it away and then charges them high rates to use it. Particularly now that the FiT is withdrawn, different voices on the island are raised, collectively and in opposition, about how to progress. For instance, the island council is weighing up its accountability if it holds public money in wind turbines.

The frustration extends beyond the islands. National Grid – a private company – has a monopoly on energy generated throughout the British Isles. Until 2016, the FiT ensured that money would be returned to those who generated renewable energy; now this is merely profit for National Grid investors. In 2016, investment in renewables became precarious. While the Scottish Parliament has issued many documents in support of the renewable energy industry, seeing great environmental, economic and social value for Scotland, its ability to step in is ultimately constrained by the fact that it never gained self-determination rights to energy after the devolution in 1999. The Scottish oil bonanza was to remain under the rule of Westminster and, consequently, Holyrood still has no control over energy production and consumption in Scotland.

After the FiT scheme closed, as the wind energy initiatives on the island reeled, *Orkney Island Council* issued its own guidance documents on energy production and consumption, stressing the importance of wind energy to the islands and its commitment to it. The company that operates most of the turbines is still financially cushioned by other windfarms in the broader region of the Highlands and Islands, but these very interests make the company less flexible in responding to windfarms without an obvious source of revenue (Kerr et al., 2017). The charity, run from Orkney, has found itself with more discretion to apply ingenuity to the problem.

Surf 'n' Turf, as mentioned above, is the research arm of *Community Energy Scotland*, engaged in investigating energy-intensive products that would turn wind-sourced energy into desirable commodities. Confronted by the absence of a revenue stream, the project is looking at the idea of converting wind and wave energy into bottled hydrogen, which can be stored and transported independent of the grid and National Grid. There are plans to send canisters to the mainland to sell it as ship fuel. Of course, if the Orcadians can find a way of using this power source directly, they will have achieved the holy grail of controlling their energy as well as the wind. The hydrogen tanks have the potential to absorb all available turbine capacity, store the energy till needed and travel easily. They would, in effect, be batteries and allow the islanders to go collectively off-grid.

In their paper *A grassroots sustainable energy niche? Reflections on community energy in the UK* (2013), Seyfang and colleagues describe community energy projects as a type of grassroots-led innovation aiming to create more sustainable energy systems. They point to situated niches as something that can "*help to diffuse innovations more widely, potentially becoming robust enough to compete with – and influence or displace – existing, less sustainable systems*" (Seyfang et al., 2013). They further argue that niches are something that mobilizes knowledge from the bottom up. As Garman (2018) says above, the incentive behind the hydrogen projects is not to create a viable business so much as to build resilience and autonomy in the island communities. And, while opinion differs about how to make headway, many years of community involvement in energy concerns has mobilized a considerable public on the islands to discuss, invest, experiment and learn.

9. Conclusion

In this essay, we have shown how technical, legal and socio-economic infrastructures have entangled to impact upon the choices open to Orkney residents. Their desire for control has been fuelled by a sense of the islands' remoteness and distinctiveness from the mainland of Scotland and, certainly, from the United Kingdom as a whole. This complex weave shows the frustrations that lack of control introduces, but also the creativity driven by this constant thwarting. As design researchers, we end by drawing attention to the creativity of the islands' people in harnessing resources and using both constraints and opportunities to shape their futures.

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Reconciling qualitative and quantitative storytelling in just energy decision making: A research design challenge contribution

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1. Introduction

Energy plays a crucial role in shaping relations between human societies and more-than-human worlds. Energy, however, never comes solely as a material reality on its own, but carries with it a large baggage of ideas and practices. Access to energy resources, production practices, transmission, consumption and subsequent waste production give direction to this socio-economic, cultural, political and technological baggage, all of which has to do with political, economic and social power (Abramsky, 2010). Moreover, as Jasanoff and Kim (2013) observe, reconfigurations in energy systems are also likely to change social infrastructures, established patterns of life, work and allocation of burdens and benefits at local, national and transnational levels. This observation becomes even more relevant in a carbon-constrained world, since maintaining not just a living but also a thriving planet would require immediate action across spatial and temporal scales.

We argue that energy decision making (and therefore policy-relevant research) today often follows *ex-post* interventions to change the prevailing pattern(s). Thus, it is a 'mess first, fix later' kind of approach. Our position is that including the multiplicity of voices (different stories, narratives, imaginaries) and the plurality of approximations (both quantitative and qualitative) before we set sail to any decision making could be a better way to go about. Then, how can a coherent use of qualitative and quantitative research help us with overcoming possible shortcomings of dominant forms of energy decision making? If energy systems are the outcomes of multiple contestations shaped with biophysical and social limitations, then the key question becomes: How can societies re-organize themselves both materially and socio-economically? What is possible, what is feasible and what is desirable turn into the crucial questions, along with concerns about justice across a number of energy decision parameters such as availability, affordability, due process, transparency and accountability, sustainability, intra-generational equity, inter-generational equity and responsibility (Sovacool and Dworkin, 2015).

In this research design challenge, we focus on the 'how' question of transdisciplinary study of energy systems and futures, taking into consideration the challenges of control. However, as Stirling (2014) reminds us, deterministic pictures of control can be problematic. Rather, our overarching aim here is to contribute to the emerging literature on energy research and social science by grounding it with contributions from three distinct perspectives (organization studies, political ecology and societal metabolism). We identify some opportunities for mending the gap between qualitative and quantitative approaches to energy research and suggest potential entry points to unpack energy decisions and their consequences, both expected and unexpected. We first start with a presentation of multiple epistemologies on energy and reflect on the multiplicity of knowledge. Then we move on to reflect on different ways of approaching energy questions including a specific focus on embracing the inherent complexity in societally relevant energy research. In the penultimate section, we turn to questions of power, scale and space. We conclude with some bottlenecks and opportunities for a truly transdisciplinary energy research that is societally relevant, just, equitable, sustainable and useful at once.

2. Multiple knowledge bases and epistemologies on energy

Countering the challenges of our contemporary predicament of staying within a 'well-below 2°C' limit (Steffen et al., 2015) at the required speed, magnitude and urgency requires local, national and international authorities, scientists, civil society and communities to act in tandem across all fronts in generating plausible solutions for a transformative energy and climate future. This means going "*beyond the cockpit-ism*" of our epistemological silos and disciplinary safe havens by avoiding a "*top-down logic of steering*" (Hajer et al., 2015). To this end, technical and engineering perspectives provide valuable inputs to environmental management and policy. On their own, however, technical solutions are unable to address key issues for environmental management, such as what the goal of management should be, how the risks and benefits of management should be distributed, and who should have a voice in decision making. The challenge of disciplinary integration of analytical tools towards low-carbon transitions is therefore an ongoing debate in the scholarly literature (Geels et al., 2016). A key challenge for policy makers and researchers seeking to develop sustainable and equitable energy solutions, then, is to identify ways of handling situations where "*facts are uncertain, values in dispute, stakes high and decisions urgent*" (Funtowicz and Ravetz, 1993). Energy is a prime example in which such conditions are dominant, and therefore exemplary of 'post-normal science'. Energy research is characterized by complexity and high levels of uncertainty, and approaches often need to be implemented before evidence is certain so that the "*traditional domination of 'hard facts' over 'soft values' [is] inverted*" (ibid.). These pose major challenges to conventional models of environmental management and governance, and require a different way of doing science. Effective and sustainable resource management in the context of complexity, interdependency and uncertainty requires new ways of working. This involves not just adding on social science to technical questions about energy, but requires a whole rethinking of how energy problems are framed by experts and politicians.

Post-normal science for environmental management and policy demonstrates the potential of adopting an extended peer community that encompasses all those affected by energy decisions rather than solely technical experts working on specific parts of the energy system. This also includes recent calls on co-design and co-production of knowledge with its users as well as those who are impacted first hand from the consequences of such knowledge (Temper and Del Bene, 2016). In other words, it goes beyond simply praising participation in decision making but also requires a fuller, informed engagement and even veto power for all parties that matter. Co-production acknowledges stakeholders as more than simply affected groups, and rather treats them as equal footing experts and knowledge generators in their own right. Thus knowledge and expertise on energy needs to be treated as decentralized wisdom rather than hierarchically organized, dictated and imposed facts. Such engagement gives all types of knowledge (written, verbal, visual etc.) equal importance as well as paying attention to non-material demands.

3. Opening the box: How energy questions are being thought and taught

Sovacool et al. (2015: 95) suggest that energy researchers often tend to "*undervalue social science discoveries, ignore possible interdisciplinary awareness, and marginalize diverse perspectives*". This, arguably, is the result of a particular framing of questions around energy as well as perceived hierarchies between multiple knowledge bases, in other words "*disciplinary chauvinism*" (ibid.). Therefore, we believe it is imperative to open the black box of framing in terms of how energy questions are posed and thought about.

The notion of control interpreted as a coercive measure (regulation) is best understood when discussed in contrast to other institutions that can be of crucial importance for change processes and inertia in future energy systems. In organizational studies and institutional theory, this is discussed in terms of coercive, normative and cultural-cognitive institutional pillars (Scott, 1995). This branch of studies is emphasizing that how we organize knowledge (categories used) and norms (values surrounding choices of technology for example) also plays important roles in understanding inertia and change processes. Some recent studies also emphasize that the different vocabularies used by groups (Ocasio et al., 2015) are rooted in practices and routines of organizations, rather than entirely based on regulatory measures. This is important to consider when analysing change processes in organizations. Applied to sectorial fields such as actors in the energy production sector, this is also of relevance for analyses of how new pathways or development paths are enabled (or disabled) in planning less carbon-dependent future energy solutions. Different vocabularies used by different groups of actors will result in the empowerment (or contrarily, dispossession) of certain stories over others. Also in future studies on multiple visions of energy systems and urban space (Larsen and Höjer, 2007; Larsen et al., 2011), the use of language is relevant to consider when analysing how future visions and technology-optimistic views of future operationalize urban space and technology choices.

Similarly, the perception of what energy entails can be subject to change over time. Both with regard to who has agency over technology, but also to how terms such as energy supply, energy demand and energy systems are used and perceived, i.e. what energy shortage means in practical terms but also conceptually are subject to change or result in new emerging properties. Shove's (2003) insightful study about the transformation of the meaning of concepts such as "*clean*" and "*cleanliness*" also demonstrates that long-term analyses are crucial and should also entail a careful consideration of the shift of meanings of the concepts over time.

Such shifts in concepts are also a key feature of an analysis of how organizations respond to and initiate change by negotiating new frames social contracts of research. This includes processes when research collaboration is negotiated between public-private actors, by creating new centres and research consortia. One telling example is the creation of scholarly centres of excellence, in some cases responding to societal challenges and in other cases defined by criteria of excellence alone, but nevertheless enabling autonomy of these centres to define their own impact agenda (Larsen and Nilsson, 2016) with broader societal relevance and acceptance.

4. Embracing complexity and multiple energy pathways

As an example of an approach embracing complexity, the pathways approach provides a framework for the analysis of how narratives and frames open up (or close down) space for social action on climate change (Stirling, 2008). Central to this approach is the recognition that there are many different ways of framing – understanding and representing – a system, whether by international or national policy actors and networks, different advocacy groups, different researchers or local people. Different framings result from choices about which elements of the system to highlight, where its boundaries are and at what scale to view it, as well as subjective and value judgments about it.

Adopting multiple scales when analysing complex systems across different levels to increase robustness of a systems approach, path dependency in acknowledgment of part-whole relationships (Koestler, 1967). It is important to note that objective functions will be different depending on the scale of analysis. For example, pushing for democratic energy sufficiency practices rather than solely efficiency, in the short term might slow down local development but in the long run, it will prove constructive in terms of living within planetary boundaries by addressing global energy justice.

Crucially, framings of systems and problems always implicate particularly favoured governance or technological solutions, and can be used to justify particular responses over others, promoting particular visions and goals. Paying attention to multiple framings and engaging with stakeholders (Leach et al., 2010) allows for elaborating on the concept of control and what it means to different groups when we see increasingly complex processes and co-production of knowledge.

As a potential entry point for handling different scales and dimensions of analysis and bridging qualitative work with storytelling, we suggest societal metabolism (Şorman, 2014) as a useful metaphorical way to depict how societies (with the analogy of the human body) and their economic sub-sectors (as the organs of the body) have part-whole characteristics. This approach is useful for the study of complex hierarchical systems, such as variegated and heterogenous energy infrastructures (Lawhon et al., 2018). Originating as a way to put biophysical economics into practice, societal metabolism looks into what types of energy flows are used within the different socio-economic sectors of the society unravelling the biophysical dimensions of energy analysis (Giampietro et al., 2011). One can use such an analogy to generate storylines based on prudent and viable scenarios of transformation limited by ecological, biophysical and social constraints. In essence, desirable futures need to be based on credible and persuasive storylines that go beyond wishful thinking, but are indeed grounded by feasible and viable transformation pathways on how to get there. Such an approach helps to ground questions such as what are the metabolisms we want to exert in the future? What are our current metabolic patterns? How do we rearrange/downscale our *societal organs* to get there?

Using the societal metabolism methodology, several studies have highlighted that a switch to an energy system based on renewable energy sources, for example, will imply lower scale of net energy output and supply for societies (Hall et al., 2009; Smil, 2005). Therefore, keeping up with some of the societal functions, that we are used to today, will entail diverting a great share of hours of paid work, energy and technological capital, from the various sectors of the economy to be invested in the operation of the energy sector itself (Sorman and Giampietro, 2013).

Other implications have been illustrated in terms of metabolisms of renewable energies and territorial requirements. Huber for example, defines the need of rethinking energy extraction and processes from a scattered distribution of "portals" and "holes" as seen in concentrated fossil resources to a forms of distributed landscapes in terms of new and renewable forms of energy provision (Huber, 2015). This, switch to renewables in metabolic terms, implies and extension and expansion of territorial needs; meaning new social re-arrangements and a reorganization of spatial characteristics that come about with emerging issues of disputes such as a global rush for land grab (Scheidel and Sorman, 2012) and conflicts associated with new, spatially extensive modes of energy production (Huber and McCarthy, 2017).

5. Production of knowledge, spaces and the actors on energy

Alternative approaches on energy in tune with work in political ecology emphasize the distributed character of knowledge and how producing knowledge reflects and reproduces relations of power "*as it involves questions about how, by and for whom, and to what effect knowledge is produced*" (Perreault et al., 2015, p. 212). These approaches also align with a growing interest in the concept of "*transformation*" (Gillard et al., 2016). A critical interpretation of transformation in the context of energy research, therefore, implies challenging different forms of societal domination over energy decisions with "*disruptive*" changes in social, political and economic spheres (Brand, 2016) and calls for radical alternatives (Temper et al., in press).

Energy provides, as Huber (2015) reminds us, the prime example of the inescapably political nature of nature-society relations. Thus it becomes the field of struggles over control (understood as property relations) and meaning (understood as identity, nationhood, etc.) of both physical and socio-political means of organization of human and non-human worlds. In doing so, political ecology approaches energy from its local focus rather than the mainstream geopolitical focus that is arguably dominant in energy research. It also seeks to avoid "*calorific obsession*" and talk of energy as a social relation mediated by historically specific political struggles (ibid.). Yet, we believe that these are not necessarily mutually exclusive approaches. A historically situated and locally relevant quantitative storytelling approach can help to advance the political and economic decisions around energy by acknowledging limitations, both physical and social.

6. Energy research revisited? Mending the qualitative-quantitative gap with narratives

In the context of energy research, a transition from one fuel to the next or from one technology to the other – even if essentially "*green*" – is not enough (Klein, 2017). Therefore, we argue that narratives, which bridge qualitative and quantitative stories about present circumstances of our societies, their potential future pathways and pitfalls, is but one opportunity to rethink energy research for a sustainable, just and equitable planet. For example, in a recent special issue Moezzi et al. (2017) direct our attention to the "*narrative turn*" in energy research, which obviously requires researchers to step out of their comfort zones to talk with each other differently, embrace multiple data sources and recognize their legitimacy, and not be stuck with their own definitions of truth. In a similar fashion, Mallaband et al.'s (2017) call to focus on how people make sense of energy beyond "*kilowattevers*" is an important contribution to this end.

The concept of narrative ecologies (Gabriel, 2016) highlights the notion of interplay between narratives and counter-narratives, thereby bringing attention to their relational nature and enabling an analysis of dynamics of narratives. These narratives and counter-narratives also point us at different methodological ways to work with data, as well as how different perceptions of 'facts' and 'data' are mobilized across disciplines. Our challenge here also aims to go beyond a review of different perspectives and disciplinary approaches to analyse energy. An example of such sort of engagement is in the making with workshops we carry out in Sweden (Stockholm, February 2018) and Spain (Bilbao, March 2018), involving energy researchers and environmental humanities scholars from various disciplines. The micro-narratives, shown below, are illustrating how participants with different disciplinary backgrounds narrate an instance of everyday life with respect to energy. The following short statements by our workshop participants reveal how their own activities and devices used and infrastructures in place are some key features of these micro-narratives as much as their disciplinary vantage point of view.

> *"Every day I use my PC and I go online. It is hard to see energy in that activity because you almost do not see the usual signs of energy. Sure the PC must be plugged as well as the router, but it is different from a car or also the train I take every day; I do not even know how much energy is needed to go online."*

Other micro-narratives have a focus on an internal use of energy, using concepts such as endosomatic energy and reflecting on the energy system as a whole, including a life-cycle perspective on food production. For example:

> *"I wake up to eat and drink, to fulfil my energetic requirement in terms of endosomatic needs based on a 2,500 kcal diet. I walk, consuming energy internally, and take a bus running on renewable energy. I see that energy is a vital part of every instance of my life."*

> *"[I think about] Endosomatic energy when I go to work, I train, I think [...] to perform my body functions. It is provided by my food that in turn needs energy from the sun to be grown and fossil fuels for transportation."*

In conclusion, we believe that there are no easy answers given the fact that societally relevant energy research in a carbon-constrained world is a marathon rather than a sprint. Such research needs to recognize biophysical limits, socio-economic and cultural factors, as well as the contentious nature of energy politics to obtain and maintain power. We argue that bridging qualitative and quantitative narratives may prove useful in thinking about alternative futures that are both not limited by the dominant politics and, in the meanwhile, not being ignorant about the physical system boundaries.

To conclude, we also pose some potential research questions that we believe remain as areas requiring further thought:

- How to transcend the dichotomies of natural sciences vs. social sciences in university and higher education institutions? To this end, what approaches of learning and unlearning can serve the purpose?
- How to engage scientists, practitioners and broader energy actors in more reflexive research design, well aware of biases and devoid of jargons of expertise? What additional role do empathy, emotions and structured dialogues play in transdisciplinary studies?

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Islands of innovation in the UK and the Czech Republic

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1. Introduction

The deployment of new energy technologies, due to the colossal capital it assumes and/or their decentralized character, is accompanied by the emergence of new collectives, such as consortia of industrialists or territorial networks. Among them, there is a growing number of collaborations between citizen organizations, like energy cooperatives, and local authorities, like cities. Following this, our research project wants to fill two research gaps by asking two questions:

1. What are the forms of collaborations, stakeholder roles, success factors and barriers in the community energy projects?
2. What similarities and differences characterize the individual case study projects?

The four modes of local governing identified by Bulkeley and Kern (2006) are starting points of our research. A key issue lies here in the potential of the collaborations to broaden and change these existing roles. Through the second question, we analyse if collaborations between community groups and municipalities can create global energy approaches.

Several scholars (Seyfang, Park and Smith, 2013) show that a significant number of community energy projects in the United Kingdom use the benefits of energy production to finance actions against fuel poverty. In Denmark, several district heating cooperatives such as *Ebo* or *Hvidovre Fjernvarme* combine production and energy-saving actions. However, new investigations are needed to assess whether collaborations between local public bodies and citizen groups develop such approaches and to what extent this is true in the CEE (Central and Eastern Europe) region, like the Czech Republic.

The social sciences have focused on describing the motivations of those involved in such experiments, such as energy autonomy (Bauwens, Gotchev and Holstenkamp, 2016; Oteman, Wiering and Helderman, 2014), local economic development (Walker, 2013; Nadaï et al., 2015), or describe the type of collaborations between citizens and local authorities (Fudge, Peters and Woodman, 2016). However, we assume that there are two gaps in this literature that we would like to fill. The first gap is that scholars mainly describe the collaborations between public bodies and community but tend to neglect questions such as roles of citizens and authorities. The second gap is that citizens' and municipalities' initiatives to produce energy are still largely addressed in isolation. As a result, energy research projects remain relatively narrow-focused. However, the combination of these activities is becoming a growing concern of the European institutions, as suggested by reports such as *Prosumer Energy and Prosumer Power Cooperatives: Opportunities and challenges in the EU countries* published by the European Commission in October 2016.

The research is based on a comparative approach with three in-depth case studies:

- The Czech Republic: 100% energy self-sufficient Kněžice village and Hostětín village
- The United Kingdom: MOZES (Meadows Ozone Energy Services)

For each case study, semi-structured interviews with key representatives were conducted.

2. The United Kingdom

Similarly to other European countries, the United Kingdom has implemented legislation with renewable energy targets as a policy goals. In the Climate Change Act 2008, the UK committed to reduce its greenhouse gas emissions to 20% of the 1990 levels by 2050. To deliver on this commitment, the government sets five-yearly carbon budgets that run up to 2032 (Ofgem, 2017). Despite these commitments, the UK still has a low share of energy coming from renewable energy and ranks among the 'laggards' within the EU: whereas the EU average of energy consumption coming from renewable energy was 16.4%, the UK ranked 24th out of 28 EU member states with 8.4% of its energy consumption from renewable energy (European Commission, 2017).

When it comes to describing energy governance arrangement, the UK is characterized as large-scale, centrally-planned or private-sector led and driven sector with a limited citizen involvement in energy planning and development (Kern, Kuzemko and Mitchell, 2014; Walker, Devine-Wright, Evans and Hunter, 2007). According to Mitchell, "*a decentralized energy system with a high proportion of renewables, appears to be only envisioned by the UK government if it is linked to large companies*" (Mitchell, 2010, p. 134). However, from 2000 onwards, there has been increased political interest in community renewables in the UK, evidenced by supportive statements in policy documents issued by successive UK governments, noting the potential of the sector and offering a range of supportive initiatives (Strachan et al., 2015, p. 101). In this context of growing interest for community initiatives, dozens of projects have been developed over the last decade. Among them, several initiatives want to combine energy generation and actions to tackle fuel poverty. These aims were at the origins of Meadows Ozone Energy Services Limited's (MOZES) creation.

2.1. Meadows Ozone Energy Services Limited (MOZES)

The story of Meadows Ozone Energy Services Limited (MOZES) began with an unsuccessful bid in 2005 for Living Landmarks National Lottery funding with the view to help the Meadows become Nottingham's first inner-city low-carbon neighbourhood (Hannon, 2012). Following this bid, a steering group was formed with representatives from Meadow Partnership Trust (MPT), Nottingham Energy Partnership (NEP), Nottingham City Council and local Residents Associations, the local MP (Alan Simpson) and National Energy Action (NEA), a national charity undertaking a range of activities to address the causes and treat the symptoms of fuel poverty. The support of the latter was a key element for the development of the project. Indeed, NEA provided funds to conduct a feasibility study for establishing an Energy Service Company ESCo in 2007. At that time, the Meadows was a relatively deprived neighbourhood of England. In 2007, 4.4% of the area's residents were claiming job seekers benefits, compared to an average of 2.3% for the whole of England (Monstadt, 2007). Furthermore, in 2007/8 the average net household weekly income was approximately £400, compared to £490 for the East Midlands area. In October 2009, MOZES was constituted as a company limited by guarantee. During the same year, members of the steering group in partnership with British Gas won a £615,000 grant from the Department of Energy & Climate Change (DECC) low-carbon communities competition. Following this, the organization installed 67 photovoltaic systems between February and April 2010.

A key success factor was the ability of MOZES to develop several partnerships with both local and national actors. Within the first category, the MPT played an important role for the development of ideas and business plans before the grant received by DECC. Another key actor was the former local MP who shared his experience and practical knowledge of community energy initiatives (he is member of several other energy cooperatives in the United Kingdom). Within the category of national actors, a significant contribution was brought by NEA. This organization shared its expertise with MOZES founding members.

Two elements have played a critical role in the limits met by the MOZES project: the difficulties to get involved with the project inhabitants of the Meadows and the policy modifications with the feed-in tariff (FiT) becoming incompatible with the previously received grant. The difficulties in community mobilization were first experienced when MOZES boards sent a leaflet to inform the 4,000 households of the Meadows that sixty solar installations were going to be offered for free to inhabitants of the area. Whereas members of the board were expecting to get a high number of applications, they only received 17 expressions of interest from the community members. Therefore they had to contact other inhabitants for the remaining solar panels. Another difficulty in community mobilization was encountered when trying to fill all the seats of the board with inhabitants. According to one of the founding members, "*every year it is a tough challenge to make sure that we are going to have enough inhabitants of the Meadows within the board.*"[1]

Regarding the policy modification, it has been outlined by one of the board members that when starting the project, the grant and FiT payments were supposed to be compatible. The income stream generated through the payments was planned to be used to install new solar panels and to reduce fuel poverty within

1 Nottingham, 26 January 2018, Personal Interview.

the Meadows. However, in April 2010, the European Commission decided that the FiT constitutes state aid. Following this decision, the DECC determined that any organization that had receive any public funding for their renewable installation above the state aid threshold (when combined with anticipated FiT payments) was prohibited from claiming the FiT (Payne and Steeden, 2012). Whereas this decision might be considered as a simple translation of EU legislation, a member of the Meadows board analysed this policy choice as "*a restrictive interpretation of EU rules because it is not about market distortion because the MOZES project is not big enough to be market distorter and it is not a commercial enterprise, it's a social enterprise.*"[2] Some analysts developed similar views about this decision, outlining that "*particularly when considered in the context of EC decisions on comparable schemes elsewhere in the EU, it is far from clear that the UK scheme should constitute state aid at the level of FiT generators such as community projects*" (Payne and Steeden, 2012). Following this decision, only two out of 57 photovoltaic installations were eligible to FiT payments.

3. The Czech Republic

The Czech Republic is self-sufficient in the electricity production, however, it is dependent on fossil fuels to a considerable extent (brown coal representing a 43% and nuclear power sources a 29% share on gross electricity production). The renewable energy share in 2016 was 11%, out of which biomass took a 2% share, biogas 3% and organic waste 0.1%[3].

Czech energy policy is framed by the State Energy Concept, whereby the latest version (2015) supports conventional electricity production, including the building of new blocks at the Dukovany and Temelín nuclear power plants. On the other hand, the Czech Republic's renewable energy policy is aligned with the European Union 2020 targets. These targets and the policies to meet them were set in the National Renewable Energy Action Plan (2011): a minimum 13% share of energy from renewable sources in gross final energy consumption is defined and reaching a 10% share of the renewable energy supply in the transportation sector is required[4]. To date, several other action plans have been published for the development of nuclear energy, energy efficiency, smart grids and clean mobility.

As renewable energy gains more attention and complying to the Directive 2001/77/EC, the national RES support is covered by the legislation, namely Act 165/2012 on promoted energy sources and on amendments to some laws. Supported energy sources include renewable energy sources (energy from biomass and biogas, solar energy, wind energy, hydro energy), biomethane, secondary energy sources, high-efficiency combined heat and power generation and distributed electricity generation. The legislative requirements include priority of the RES connection to the transmission or distribution grid. The promotion of the supported electricity production is based on two main financial instruments:

1. Feed-in tariffs (FiT): guarantee retail prices for RES plant operators for a given period;
2. Feed-in premium (FiP): plant operators need to market the electricity at the electricity market and receive an additional payment on top of the electricity market price (green bonus payment).

The promotion of RES is also financed via fiscal incentives – regulated tax calculated as a component of the electricity price on final electricity consumption. Investments for renewable energy production are financed from the state budget via several subsidized programmes such as green savings or the state programme to promote energy savings and use of renewable and secondary energy sources (EFEKT). The operational programmes are financed by the EU structural funds.

The share of RES in total primary energy supply (TPES) increased from 5.2% in 2008 to 13.2% in 2014 despite claims that the potential of RES is limited due to limited natural conditions (see Figure 1 for the

2 Nottingham, 26 January 2018, Personal Interview.

3 Gross electricity generation: 83.3 TWh, based on ERU (Energetický regulační úřad) 2016. Available at: https://www.eru.cz/cs/elektrina/statistika-a-sledovani-kvality/rocni-zpravy-o-provozu [Accessed 13 March 2018].

4 Based on the Directive of the European Parliament and of the Council No. 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources for the Czech Republic. Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0028 [Accessed 13 March 2018].

latest 2015 international comparison). Rapid progress was mainly driven by the solar thermal and PV sector boom, supported by FiTs. In 2013, the Czech government decided to stop the premium tariff scheme except for small hydros. As a consequence, since the beginning of 2014, the FiT for biogas plants (and other types of RES) has been stopped. Tariff levels for biogas plants put into operation before December 2013 depend on the date of commissioning. Such market uncertainty caused decreased interest in RES investments and since 2013, there has been little growth in the RES sector.

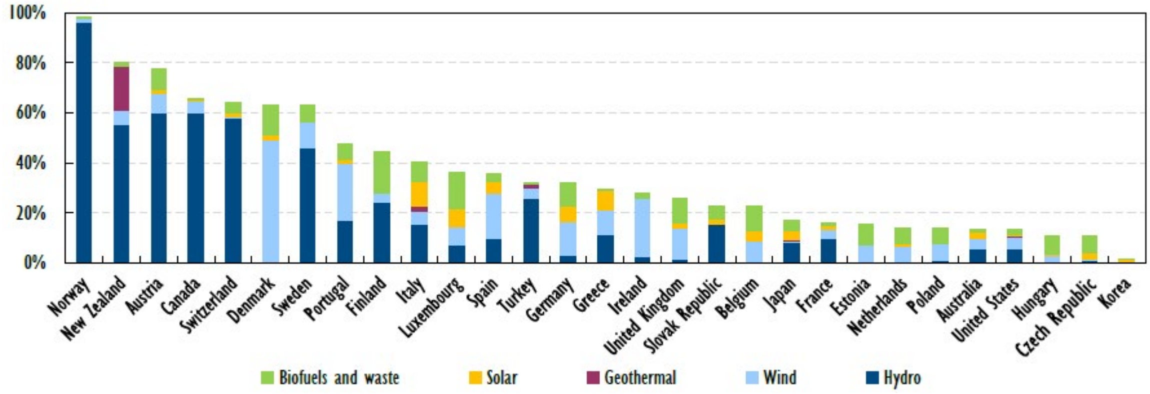

Figure 1 – Electricity generation from renewable sources as a percentage of the overall generation in the Czech Republic and IEA member countries, 2015 (IEA, 2016). Source: © OECD/IEA 2016, Energy Balances of OECD Countries 2016, www.iea.org/statistics/

Based on the International Energy Agency's (IEA) in-depth review, the Czech Republic has made good progress in the implementation of its energy policy. There is a need to replace the support schemes with stable measures. Alternative possibilities could include auctions of capacity from renewable energy production or a share/quota of the electricity they supply coming from renewable or green certificates. IEA states that there is clear potential for the further development of biogas stations and solar PV. Electricity generation from biomass and waste should continue to develop and the two following unique Czech examples might be presented as best practice.

3.1. Kněžice self-sufficient village

Kněžice at Městec Králové is a village located in the central part of the Czech Republic in the Nymburk district. There are 410 inhabitants living in the central part of the village and approximately 100 people in two distant areas. Most of the people living there are employed in the industrial sector in the nearby located automotive companies (Škoda Mladá Boleslav and TPCA).

The municipality is very actively involved in the communication with regional and national authorities and non-profit organizations, such as Greenpeace, Association BIOM and the local government. The municipality is actively participating in the initiative called *Coalition for renewable energy support*, co-operating with the local Friends of Europe organization DUHA. Moreover, co-operation with Czech universities is supported as well.

Kněžice is an energy self-sufficient municipality producing heat and electricity from biodegradable waste since 2006, when biogas station and biomass heating plant started to operate. The biogas station is located in the northern part of the village, processing waste such as grass and leaves from municipal areas, waste from households, septic waste and canteen leftovers. The closed cycle generates electricity for sale to the grid and heat energy for local consumption. The residual waste (biogas station digestate and ash) is used as liquid fertilizer in the local fields. The biomass heating plant processes wood chips and straw, their own production of wood pellets started as well.

In total, 159 central heating connections were connected within the central heating system, thus representing 90% of the overall households. The heat produced is directly sold to the end customers. The locally generated electricity is delivered to the ČEZ Distribuce grid and subsidized by the Energy Regulatory Office via green bonus payment (category AF2).

The biogas station is operated by the company Energetika Kněžice, s.r.o., which is 100% owned by the municipality. The financing scheme relied on several types of sources: international funding (European Fund for Reconstruction and Development), Czech national funding (Czech Environmental Fund) and the residual amount was covered by a bank loan. The households participated financially as well, CZK 10,000 for each heat connection.

The main motivation for the implementation of the project was the ‘back to the roots’ philosophy in the context of circular economy principles. Improvement of living standards and better land use were taken into account. The avoided cost of a potential sewerage and waste management system was assumed around CZK 40 million and that of natural gas pipelines CZK 15 million. Reflecting this, the financial aspect was important in the beginning, providing the project with financial payback. However, the most important success factor in the initial phase was convincing the inhabitants. Intensive personal meetings with the mayor and municipality representatives were needed to explain and discuss arguments for the installation.

3.2. Hostětín village

Sustainable development of rural communities is also represented by the second Czech example Hostětín, a village located in the White Carpathians. The number of inhabitants in this small village amounts to approximately 240. The region has been fighting with a high unemployment rate due to a transformational crisis in 90s, when industrial production changed and the agricultural sector went through restructuring as well.

The holistic philosophy of the Hostětín projects is based on sustainable local development. The bioenergy solution was already started with treating waste water. A reed bed sewage system was built treating waste water with bacteria living on the plant roots. Later, the following projects were added:

- 9 solar thermal installations at family houses and the local juice plant
- 2 PV collectors for electricity generation: at the juice plant (with seasonal fluctuations)
- and at the biomass plant
- Other projects including public lighting system

The municipal biomass heating plant was built in 2000 and heats almost the entire village Hostětín. The heat distribution network (2.8 km long) is connected to 83% of the households (70 out of 86 buildings in total) and the plant is burning wood chips, waste from sawmills and forests.

The main motivation in this case was local economy support based on the sustainable development and related positive effects from energy self-sufficiency: significantly cleaner air, reduction of heating costs and also lower population decrease. The collaboration between the village representatives, non-profit organization Centre Veronica Hostětín and foreign experience was described as one of the most important initial success factors.

Several barriers had to be overcome at the beginning. First interest screening discovered only 50% support for the biomass station project. Information campaigns were conducted, best practice examples explained and shown. Similarly to the previous case study, financing schemes were very complicated, involving many stakeholders. Later, material supply problems turned up as the wood chips suppliers changed and no long-term supplies could have been agreed on.

4. Conclusions

The following comparative table summarizes the case study results:

Renewable energy project	**Meadows OZONE**	**Kněžice**	**Hostětín**
Starting year	2009	2006	2000
Ownership structure	Company limited by guarantee	Municipal ESCO	Municipality
Financing scheme	Grants from the Department of Energy & Climate Change (*DECC*)	ERDF, Czech Environmental Fund, commercial loan, citizens	Dutch state funding, Czech Environmental Fund, Czech energy agency, citizens
Technology	Photovoltaic panels	Biogas station, biomass heating plant	Biomass heating plant, photovoltaic panels
Aims	Tackle fuel energy poverty	Circular economy principles	Sustainability, Local economy
Barriers	Policy modifications (impossibility to combine the FiT payments and the grant) Difficulties for community mobilization (low interest at first for solar installations, reluctance for being a member of the MOZES board)	Unpredictability of the energy policy	People's initial resistance Isolated energy policy concepts
Success factors	Support from external organizations (NEA, MPT) Grant funding Expertise from actors with strong knowledge of community energy issues (local MP).	People and successful awareness raising Grant funding	Strategic partnerships Grant funding

When looking at the three case studies, several similarities and differences appear. Within all of them, the development of energy activities was rather a tool to tackle other issues than an end in itself. The rationales behind these projects were highly related to local development and socio-economic questions. Besides the differences in terms of technology (biomass, biogas and photovoltaic) from one project to another, a similarity lies here in terms of socio-technic complexity. All the technologies mentioned before can be considered as energy infrastructures which are relatively easy to put up, even more if we compare them to onshore and offshore wind power. Following this, an interesting question will be to assess to what extent municipalities are able to develop more complex and capitalistic technologies.

When it comes to the differences between the case studies, a distinction can be made between the governing modes of local authorities. Whereas both Czech projects are related to self-governing and governing by provision modes - which are the capacity of local government to govern its own activities and the shaping of practice through the delivery of particular forms of service and resource (Bulkeley and Kern, 2006) - the British project is related to governing through enabling. The latter corresponds to the role of local government in facilitating, coordinating and encouraging action through partnership with private- and voluntary-sector agencies, and to various forms of community engagement. We need to specify here that in the MOZES case study, these facilitation and co-ordination roles have been relatively low, with the local council only having one civil servant attending board meetings of the organization from time to time. This difference in terms of governing modes between the three case studies raises a key question: What makes the local authorities adopt a governing mode?

Following our research, two main conclusions can be made:

1. A local authority is more likely to adopt an unusual or innovative governing mode if this authority is integrated within a broad coalition of actors.

2. A local authority is more likely to adopt a mode of governing through enabling if citizen or community groups are able to raise funding by themselves (e.g the grant won by MOZES from the Department of Energy & Climate Change (DECC) low-carbon communities competition).

Finally, future recommendations from the authors include the currently underestimated co-operation of eastern/central and western European countries in energy research.

5. Acknowledgements

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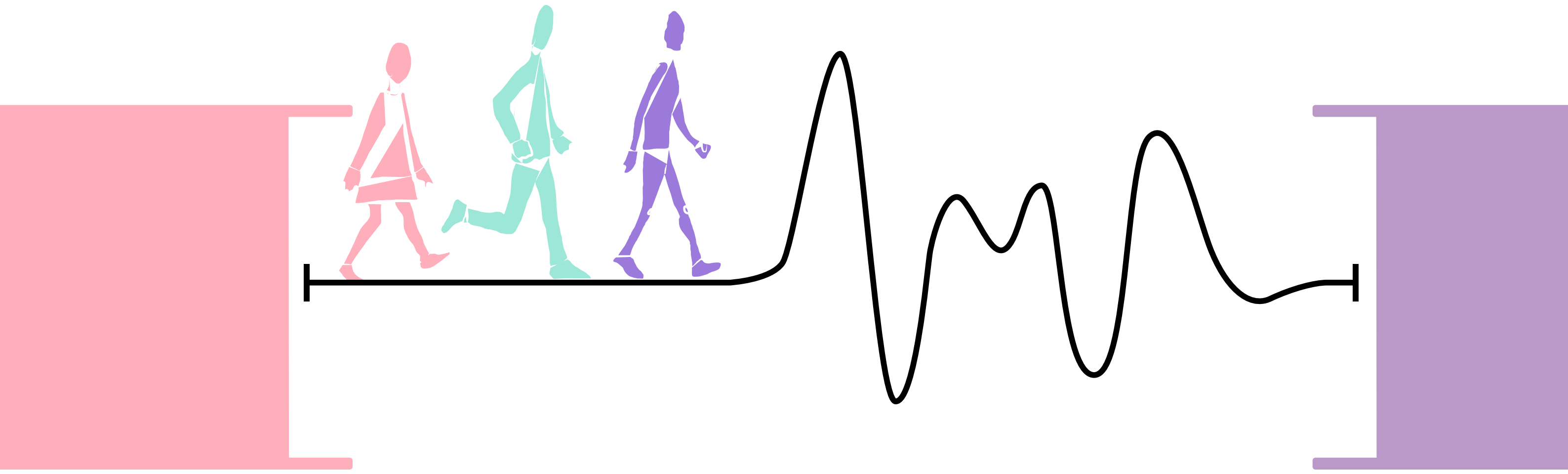

SECTION B
‘Stability and Change’ in energy systems

Buchmann, K.; Heffer, Sh.; Parag, Y.

Energy pioneers: Energy start-ups, ecovillages in Israel and Germany

Greene, M.; Schiffer, A.

Learning from past and current energy transitions to build sustainable and resilient energy futures: Lessons from Ireland and The Gambia

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Feeding back or feeding forward? A new lens into building energy use

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Towards a stronger integration of spatial perspectives into research on socio-technical transitions: Case studies in the Swiss energy sector and the German transport sector

Energy pioneers: Energy start-ups, ecovillages in Israel and Germany

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1. Introduction

Reduced energy consumption and a switch to renewables are crucial to limit climate change – there is an urgent need for an energy transition. In this energy transition, some have pointed to the important role of "*pioneers of change*" (Andreas and Wagner, 2012, p. 6). This transition requires a fundamental shift in both supply and demand. We thus here focus on two pioneers: Ecovillages (EV, demand) and energy start-ups (ES, supply). Whereas start-ups provide market innovations, ecovillages are grassroots innovations (Seyfang and Smith, 2007, p. 592). To structure our enquiry, we chose to examine ES and EV as niche-innovators in a multilevel ecosystem with the potential for a sociotechnical sustainability transition. We thus focused on these niche-innovators and their relationship to the government, larger companies and wider society. Hereby, we paid special attention to the extent to which ES and EV represent radical divergence ('outside'), including their disruptive potential, versus conformity ('inside').

We conducted 14 semi-structured interviews with start-ups, ecovillages and government agencies. We additionally organized a roundtable with start-ups and ecovillages to discuss these topics and toured Israeli ecovillages.

Geels assesses how niche-innovations are taken up by wider society and transform dominant practices. The multilevel perspective's (MLP) core consists of three levels:

1. Macro-level (landscape): Society, socio-cultural background
2. Meso-level (regimes, institutions): Governments, mature companies
3. Micro-level: Innovators, niche-actors, experimentation.

The meso-level, government and incumbent firms, through various lock-in mechanisms, may prevent niche-actors from breaking out. The MLP focuses on the niche-innovators, "*where radical variety is generated*" (Geels, 2002, p. 1272). "*Niches are 'protected spaces' (such as [...] start-ups). [...] Niche actors hope that their promising novelties are eventually used in the regime or even replace it. [...] Niches are crucial for transitions, because they provide the seeds for systemic change*" (Geels, 2011, p. 27). Geels identifies three core functions of niche-actors: the articulation of visions for "*attention and funding from external actors*", "*building of social networks and enrolment of more actors*" and "*learning [...] on various dimensions*" (Geels, 2011, p. 28). Destabilization of the existing regime is crucial for transition to another regime, for niche-innovations to become mainstream (Geels, 2002). The *Energiewende* has been identified as such a regime shift (Strunz, 2014). Geels sees the MLP as middle-way between "*radical sustainable consumption and production*" (SCP) and reformist SCP perspectives (Geels et al., 2015). While initially, scholarship pertaining to niches "*focused on [...] business-led technological innovations*", Seyfang et al. advanced an agenda on "*radical community-based action for sustainability as an overlooked site of innovation for sustainability*" (Seyfang et al., 2014, p. 24). Our study combines both.

2. Ecovillages

In 1987, Hildur Jackson, who had lived in an Israeli kibbutz (Joubert and Dregger, 2015; Pais, 2015), and two hedgefunders started the *Gaia Trust Strategy*, combining an "*emphasis on yin (how we want to live with each other and the natural world) with support from yang (technology and economy)*"[1]. They wanted to fund both technology and sustainable intentional communities and tasked the *Context Institute* NGO to collect best examples. Indicators included "*the use of renewable energy sources (solar, wind, etc.) rather than fossil fuels*" (Gilman, 1991). Ecovillages identified met to discuss how the Gaia Trust could help them. The Global Ecovillage Network (GEN) was then established in 1995 (Leach, 197). In this manner, the ecovillage movement was an energy niche-innovation created with the help of actors at the meso-level who combined two different societal trends (macro-level) at the time – a focus on technology, economics and hedgefunds

1 Hildur Jackson obituary, http://gaia.org/gaia-trust/hildur-jackson/ [Accessed 12 March 2018].

with the (re-)emerging environmental movement. Existing definitions do not pertain to energy use outcome, but rather towards an intention, which could result in an attitude-behaviour gap[2].

The following section will address the interaction of the niche-actors 'ecovillage' in Israel and Germany with the landscape macro-level, society and culture – with the 'inside'. This will compare the socio-cultural background that gave rise to the ecovillages in Israel and Germany and the interaction of meso-level (government) with niche-actors.

As aforementioned, the EV movement was directly inspired by the kibbutzim. While Israeli ecovillages are mostly kibbutzim, few kibbutzim are ecovillages[3]. Three, including Lotan and Ketura, are in walking distance from one another in the desert near Eilat. All are religiously 'niche' – Lotan is Reform Jewish and Ketura 'pluralistic'. Kibbutzim were colonists' settlements that originally operated on socialism and agriculture. Kibbutzim determined the 1947 borders of Israel (Gavron, 2000, p. 5). While the kibbutzim's symbolic meaning for Israel can hardly be overemphasized, only 2% of its population lived there (Lubell, 2015). Kibbutzim always received state support, including debt cancellation. In 1958, the kibbutzim were assigned by the Ministry of Agriculture to banks that provided credits without proper financial risk analysis, a kibbutzim-government transfer mechanism (Navon, 2010).

German ecovillages developed differently from kibbutzim, in the wake of Chernobyl and the 1980s environmental movement. The initial vision of Sieben Linden (SL) was formed in 1989 (the actual village was founded in 1997). In contrast to Israel, the initial seeds for ecovillages were not governmental, but within the wider societal context of the environmental movement. The number of ecovillages founded in Germany doubled after reunification (Lambing, 2014, p. 29). While kibbutzim historically fit societal values (elite 'insider'), the foundations of German ecovillages were more radically 'outside' of mainstream values.

A severe destabilization then brought about a new regime in Israel, which ultimately led to the reorientation towards ecology of some kibbutzim. In this case, regime destabilization thus led to a new niche-within-niche creation. The last traditional Jewish kibbutz to be founded was Kibbutz Lotan in 1983 (Miles, 2003), which today is an ecovillage and one of our case studies. Since the 1980s, kibbutzim experienced a severe decline. This was rooted in debt and party politics – in 1984, Israel experienced an inflation rate of 450%. All sectors' debt except kibbutzim's was renegotiated, because Peres "*want[ed] to embarrass his bitter rival, Yitzhak Rabin, the kibbutz movement's political patron. [...] [K]ibbutzim didn't receive [...] debt restructuring until 1989 [...] [when their] debt was near $6 billion [...] Draconian debt repayments were [...] driving down living standards [...]. Members with marketable talents began leaving*" (Goldberg, 2010). Society's relationship with kibbutzim changed drastically: "*Israeli society had always looked to the kibbutzim as an elite group. But now they were regarded as a mere interest group that depended on money from the state*" (Buck, 2010). After this debt crisis, most kibbutzim changed beyond recognition – from socialism to privatized capitalist entities.

Lotan was in a severe crisis in 1996, when one third of its members left: "*The siren call [...] of normative western society was too strong.*" (Livni, 2008, p. 3) Lotan thus needed new 'roots', a new niche, and settled on ecology in their new mission statement (Miles and Weissmann, 2004, p. 92). This was very much in line with certain existing societal trends, the landscape, the founding of GEN being in 1995 (Leach, 2016, p. 197). Lotan established the *Center for Creative Ecology* in 1997[4], which offers Green Apprenticeship courses[5].

At the same time, in 1996, neighbouring Ketura founded the *Arava Institute for Environmental Studies* for Israeli, Palestinian and Jordanian students. Today, the Arava Institute has four research centres, including for renewable energy (RE) and energy conservation. Current research includes RE acceptance by off-grid communities[6]. The Institute is working to use RE as leverage for development[7] and operates the 'Off-Grid

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2 See Boulstridge and Carrigan, 2000. "*An Ecovillage is not a particular outcome, but an ongoing process.*" (GEN, "What is an ecovillage", available at https://ecovillage.org/projects/what-is-an-ecovillage/ [Accessed 12 March 2018].

3 See GEN-Israel: http://gen-israel.org/about-us/ [Accessed 12 March 2018].

4 http://kibbutzlotan.com/cfce/consultancy/?lang=en [Accessed 12 March 2018], Interview Kibbutz Lotan.

5 Interview (2 February 2018) and visit Lotan, 16 February 2018.

6 Meeting A Ketura, 15 February 2018.

7 Meeting B Ketura, 15 February 2018.

hub', showcasing energy-efficient technology built by students, including a HomeBiogas digester. Ketura raised money for the affiliated start-up with a kickstarter[8]. HomeBiogas is not used by the communal dining hall[9].

In the 2000s, further governmental pressure led to another transformation: Since a kibbutzim law change, the number of collective kibbutzim has dropped continuously to about 27 (2018)[10]. Kibbutzim thrived when aligned with macro-level and meso-level – today they are not seen as necessary[11].

The traditional collective kibbutz has a different energy profile from the privatized, 'renewed' kibbutz, as shown in the table below. Neither Lotan nor Ketura charge members individually for electricity, which concerned some that this may lead to "*laziness about conservation*" (Swennerfelt, 2011). To survive financially, Lotan took in paying non-member residents in 2001 who in contrast to members have electricity meters and are charged individually for their electricity use (Cohen et al. 2010, p. 24). At this time of renewed crisis, Lotan declared itself an ecovillage and joined the GEN[12].

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Table 2 Characteristics of the four case study kibbutzim along a gradient from more collective to more private

Kibbutz	Size of largest homes (m^2)	Common dining room	Dishwashers in member homes	Clothes washers in homes	Members working off-kibbutz (%)	% of non-members[a] (%)	Charging for household electricity	Level of privatization
Ketura	80	Used by most for 3 meals	Not allowed	Not allowed	46	10	Not charging	More collective
Lotan	80	used by most for 3 meals	Less than 1/4 have	Less than 1/3 have	32	29	Information without charging	↕
Grofit	90	used by less than half for 2 meals	Less than 1/2 have	Almost all have	49	46	Charging with itemized budget	
Yahel	125	used by less than half for 2 meals	More than 1/2 have	All members have	42	60	Regular charging	More private

[a] Paying residents in adult population

(Source: Cohen et al., 2010, p. 23). Republished by permission from Springer Nature, Energy Efficiency, Cohen et al., 2010.

The national government wanted to close Lotan[13]. Lotan tried to attract new members and found that energy-efficient building was too expensive for some new members, yet Lotan had to take them (Levine, 2015, p. 46)[14]. At the same time public funding for the houses went down[15]. Because Lotan could not raise the money necessary to build enough new housing, Lotan was forced to privatize in 2015 (Levine, 2015, p. 45)[16]. The ecological niche has provided Lotan with a 'market benefit' (Miles and Weissmann 2004, p. 91). "*Everyone wants to move here because it's called ecological*"[17]. This was also what was emphasized to attract new members: "*When we decided three years ago what we wanted to do and how we should market it to get young people to move here, we decided to market it as a Jewish environmental community*"[18]. Lotan was not able to make it mandatory for new members to build energy-efficiently[19].

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8 Tour Guide Ketura, 15 February 2018.

9 Ibid.

10 Ibid., תליחתל בצמ תנומת – םיפותיש םיצוביק http://kibbutz.haifa.ac.il/images/publications/shitufi2017.pdf [Accessed 16 March 2018].

11 Interview Lotan.

12 Interview Lotan.

13 Ibid.

14 Ibid.

15 Ibid.

16 Ibid.

17 Ibid.

18 Ibid.

19 Ibid.

Concerning regional politics, Lotan could not exist without a very specific local regime: "*Lotan could not survive outside of the framework of the Eilat region rural council where cooperative Kibbutzim set the tone*" (Livni, 2008, pp. 7/8). The Arava Institute and Ketura pushed for the regional authority championing RE further, which led to a situation whereby Eilat is the only regional authority to have an RE council[20]. The head of the Arava Institute tried to start a green kibbutz movement, but found very few takers (Leach, 2016, p. 204). Ketura is also engaged in ecological political movements in other ways: two founders of Israel's Green Party are from Ketura (Fishkoff, 2012)[21].

After successfully 'battling'[22] the government for years ("*battles involving two dozen agencies [... from] the Israeli Agriculture Ministry [... to] the local planning agency on [...] zoning changes and renewable energy quotas*"), Ketura has a large solar field that produces 70% of Eilat's power – Israel overall only has 2% solar energy (Lidman, 2015) and its affiliated company is "*now the leading commercial developer of solar power in Israel [$2 billion]*" (Kershner, 2012). Thus niche-actor Ketura has been at the vanguard of regime change in Israel and has been successful in its region, where it has evolved from niche to mainstream actor. As our guide told us "*We want to set the standard for Israel in renewable energy*"[23].

The relationship between these niche actors, ecovillages in Germany and Israel, and the meso-level, the government, is very different:

> "Kibbutz by law is an entity recognised and administered by the government. Which is interesting, because communes and ecovillages are a revolutionary idea, but in Israel there is a dedicated law, the Cooperative Association Laws, which dictate land appropriation, zoning, financial responsibilities and governance"[24].

Regarding German ecovillages, just like Lotan, SL was a pioneer in straw-bale building and achieved a law change here (Kunze and Hielscher, 2016, pp. 8/9). While on a much smaller scale than Ketura, SL was a key force in the instalment of solar panels in the area (Kunze and Hielscher, 2016, p. 9), as was ZEGG for the regional energy transition (Dawson in Lockyer and Veteto, 2013, p. 228). SL started an energy transition group for the local village (Andreas, 2015, p. 230). Interactions with the regime other than ultimately successful disputes with bureaucracy over straw-bale housing[25] include the local authority forcing SL to stop using wells for drinking water and instead transport water from 10km away (Kunze and Hielscher, 2016, p. 13).

Relations with local villages can be complex – SL inhabitants are stereotyped as 'bums' abusing state benefits. Neighbours believe ecovillagers get "*everything handed to them*". Yet SL received the same solar funding as anyone else[26]. SL'ers try to emphasize how hard they worked to build the houses to appeal to German values, try to highlight the aspects that fit in the existing socio-cultural background and de-emphasize the more radical social aspects[27] (Centgraf, 2009, pp. 51-54/63). Centgraf quotes one of her interviewees as saying that Berlin students may know more about SL than people living nearby (2009, p. 54). SL'ers are deemed outsiders: "*I don't even know what to talk about with people from the Altmark*" (Andreas, 2015, p. 229). Another neighbour criticized the destabilizing force of SL and instead wished it to conform for strongly with existing societal norms (macro-level): "*Does innovative always have to mean exemption permission or can't one be innovative and live in the existing norms and conditions*?" (Centgraf, 2009, p. 55)

20 Meeting B Ketura.

21 Tour Ketura.

22 Solar panels on the ground were forbidden. They were only allowed on the rooftop as land was considered too precious in Israel. After the battles of Ketura-ite Abramowitz, the law was changed.

23 Tour Ketura. To build the solar field, Ketura closed its dairy production, decreasing its energy footprint further. See also Kershner, 2012.

24 Interview Lotan.

25 Interview SL, 4 January 2018.

26 Ibid.

27 Ibid.

The following segment will delineate aspects of conformity and radicalism of ecovillages (insider/outsider status). At the societal level, there is a focus on the ecovillages that is completely incommensurate to their tiny size (all in our survey under 150 people). Whereas the interactions with local mainstream/regime actors can be complex, SL is often used as national example and beacon for sustainability, which leaves some of them feeling 'abused', both by national government that uses them as adorning laurels to showcase the respective country's sustainability and by unrelenting researchers[28]. There is such attention on SL that "*surrounding hotels profit from the public interest, because we always put the film teams there*" (Centgraf, 2009, p. 82). While "*large sections of mainstream society are looking toward ecovillages and seeking to learn from their experience*" (Dawson, 2013, p. 228), this also leads to a 'fig leaf' effect, whereby the ecovillages are deeply engrained in the social imaginaries as the revered locus of sustainability, yet wider society continues as before. Akin to Haredim radically living religion, also on behalf of Israeli secular society, sustainability responsibility is transferred to the ecovillages: "*Lotan has achieved a considerable reputation in Israel for its ecological initiatives. For example, Kibbutz Lotan was featured on the cover of El-Al's in-flight magazine*" (Livni, 2008). All ecovillages surveyed see themselves as 'models', e.g. SL sees itself as "*socio-ecological model*" and "*research project for future-oriented lifestyles*" (Centgraf, 2009, p. 33) and ZEGG already has this in its name. The aforementioned intense focus is key to the EV's economic survival (Lambing, 2014, pp. 35/45) – Lotan has 8,000[29] and ZEGG 16,000 tourists annually for 100 ecovillagers[30]. Due to the large number of visitors, ZEGG cannot produce all its food sustainably onsite anymore (Dawson, 2013, p. 228). Our SL interviewee spoke of the "*zoo effect*"[31]. Since there are so many visitors, there are separate areas, meals and pathways for the visitors and the ecovillagers[32].

Turning towards ecovillages' radicalism, EVs are foremost intentional communities, with spiritual aspects and only then is the 'ecovillage' as attractive label added[33]. Ecovillages' democratic decision-making is deemed key for a sustainability transition. This includes rejection of unsustainable individualism (Lambing, 2014, p. 84)[34]. To achieve sustainability, overcoming jealousy/possession and monogamy are deemed necessary. While some of the spiritual engagement remains radically divergent, two aspects that are among the most radically divergent compared to the societal landscape, sexuality and collectiveness, are slowly seeping into the mainstream as polyamory and co-housing. Recently, the ecovillages' collective decision-making has been assessed for its potential in democratic climate mitigation (Fischer, 2017, p. 194). This collectiveness also deradicalizes – SL'ers and ZEGG'ers have less time than others for political engagement or demonstrations due to a preoccupation with internal politics[35]. The most radical energy-specific segment of SL was 'Club99', a core group of four people[36] who from 1999-2011 (Kunze and Hielscher, 2016, p. 6/7) attempted to live and build without any non-human/animal energy and only local produce[37]. The experiment was ultimately abandoned as too difficult. One of the Club99'ers works for a natural cosmetics company today and for this flies more, justifying this with being a 'change agent'[38]. The habit of giving even more minute groups of friends such as 'Club99' names, is further testimony to a disproportionate societal claim. Animal husbandry and pets are forbidden in SL. SL and ZEGG limit phones and Wi-Fi.[39]

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28 Interview SL. Lotan and SL were part of the UN Decade for Sustainability Education – for SL Centgraf, 2009, p. 34, for Lotan: http://kibbutzlotan.com/cfce/consultancy/?lang=en [Accessed 12 March 2018].

29 Interview Lotan.

30 Interview ZEGG, 29 January 2018.

31 Interview SL.

32 Interview SL.

33 Roundtable SL (14 February 2018). Compare "*Ecovillages do not focus solely on ecology [...]. Preservation and restoration of nature can only succeed when the social fabric is strong, cultural heritage is celebrated and people find ways to marry their love for the planet with their need to make a living.*" https://ecovillage.org/projects/what-is-an-ecovillage/ [Accessed 12 March 2018]. Referred to at GEN's founding as ecovillages' four elements: 'Air (Culture/Spirituality), Water (Infrastructure), Fire (Social Structure) and Earth (Ecology)'.

34 Interview SL.

35 Interview SL, Interview ZEGG. See also Wallmeier, 2015.

36 Interview SL.

37 Interview SL.

38 Interview SL.

39 Interview ZEGG, Interview SL.

Possibly due to the different original regime context, there is a distinct difference between Israeli and German ecovillages: When touring Ketura, one SL'er mentioned that SL inhabitants would be too dogmatically against corporations to allow partnering with large energy companies[40]. Potentially resulting from the emergence as branding in crisis, there is an issue of implementation: "*One who visits Lotan's website and then conducts an in-depth visit will be struck by the apparent dissonance between the vision and reality*" (Livni, 2008, pp. 7/8 "*[S] imply having a dairy farm is wasteful because cows require six showers per day to stay cool in the summer months*" (Levine, 2015, p. 43). In addition, water in Israel is heavily related to energy use due to energy-intensive desalination[41]. Because of the remote location of Lotan, no railway access and planes being cheaper than buses, one interviewee takes 84 domestic flights annually plus three transatlantic flights[42]. This contrasts with SL's carbon footprint – 25% of the German average in 2002 (Daly, 2017, p. 1367). A more recent study found that its energy usage had even improved[43].

3. Start-ups

Start-ups are classified through the company's youth, small size[44], focus on fast growth, focus on technology, large potential, innovation and sometimes culture (Ireland, 2017). 'Energy start-ups' (ES) were defined by Lau as those who "*with their products, technologies and services [...] contribute to the environmentally friendly production, storage and distribution of energy, to improved energy efficiency and to the support of sustainable mobility*" (Lau, 2018, p. 35).

Hajer explored how business and technology fixes for environmental problems, such as ES, became the dominant ideology – the prevailing regime (Hajer, 1995). It can however be observed that ES fit into different landscapes in Israel and Germany – Israel lags far behind in RE. Conversely, whereas Israel is the "*Start-up Nation*" (Senor and Singer, 2009), in Germany SMEs and incumbent firms have long been venerated. While Israel reached no. one in the WWF Global Cleantech Innovation Index, Germany is more successful at cleantech start-up commercialization (Parad, 2017). One of our interviewees highlighted the role of the Middle East conflict for start-ups in Israel – technology start-ups with military usage are well-financed by the government[45].

At the meso-level, the ES ecosystem consists of government, incumbent companies and investors, including venture capital (VC). Concerning mature firms, Geels (2011, p. 25) writes that "*[D]omains where sustainability transitions are most needed, such as [...] energy [...] are characterized by large firms [...] [with assets which give them] strong positions vis-à-vis pioneers that often first develop environmental innovations. [...] [L]arge incumbent firms['] [...] involvement might accelerate the breakthrough of environmental innovations if they support these innovations with their complementary assets and resources. This would, however, require a strategic reorientation of incumbents who presently still defend existing systems and regimes*". Ball suggests ES rather than the incumbent firms will exhibit a business sustainability transformation: "*Since green new ventures are free from the innovatory constraints faced by incumbent firms, they are in a position to disrupt existing unsustainable markets.*" (Ball, 2016, p. 4).

Incumbent firms face the challenge of the so-called "*green prison*", whereby the market rewards cheapest, thus non-sustainable production processes and therefore competition leads to a "*race to the bottom*" (Pacheco et al., 2010). Ecopreneurship (Volery, 2002) will thus be "'inefficiently low' as [...] 'impure public good'" (Ball and Kittler, 2017, p. 2). The government is pivotal in "*alleviat[ing] the environmental market failure which besets eco-innovation and, therefore, minimiz[ing] entry barriers in the energy market for start-ups*" (Ball and Kittler, 2017, p. 10)[46]. The government can set energy efficiency standards, induce or aid demand

40 Interview SL.

41 "*Israel's water supply consumes almost 10% of national electricity production*" (Tal, 2018, p. 2).

42 Interview Lotan. Lotan owns only about two cars (Miles, 2003, p. 146).

43 Interview SL.

44 Average employee number for German energy start-ups: 10 (Lau, 2018, p. 84).

45 Interview German start-up E, 18 January 2018.

46 Interview Ministry of Environmental Protection, Israel, 25 January 2018.

and provide financial support through feed-in tariffs and grants (Ball and Kittler, 2017)[47]. The importance of government can be seen by the collapse of PV start-ups after the reduction of Germany's feed-in tariffs (Lau, 2018, p. 95). Israeli ES highlighted that the relevant financial support is geared towards general high-tech rather than addressing ES' needs arising from a longer "*Valley of Death*" – innovation period prior to commercialization (Gaddy et al., 2016). Randjelovic et al. (2010) claim that it remains difficult for ecopreneurs to access VC, as venture capitalists expect faster returns than eco-innovation can deliver. The same issue concerns large companies' disinterest due to shareholders expecting faster returns[48].

Start-ups are identified, on the one hand, as potentially disruptive forces – radically different from incumbent firms and 'business as usual'. "'*Startup is a state of mind' [...] startups work hard and fast to innovate and change our ways of working or living*" (Ireland, 2017). Previous research (Sauermann, 2017) identified a cultural difference between start-ups and established companies, concerning independence and risk aversion. On the other hand, the aim of start-ups, including ES, is to become an insider, a mature company – which carries with it the dangers of innovation potential loss[49] (Egan-Wyer et al., 2018). Environmentalism may be a great force in recruiting employees for the ES[50], but was not deemed as relevant for selling the product[51].

4. Conclusion

In Geels et al.'s (2015) classification, EV represent the revolutionary SCP paradigm, ES align with the reformist SCP paradigm, the "*orthodoxy*" (2015, p. 4).

Whereas both Israel's and Germany's 'landscape' is growth (ecological modernization paradigm), Germany has a greater emphasis on RE and a different relationship to start-ups versus established companies. While the former benefits ES in Germany, the latter aids ES in Israel. In this context, ES are insiders and outsiders at the same time in both national contexts. Whereas start-ups are conform, yet radical, ecovillages might be seen as radical, yet conform. While the different landscapes between the countries influenced the financial support given to the start-ups, both countries' start-ups are facing similar challenges that relate to the 'green prison'.

Concerning ecovillages, our German cases are more radical in their energy approach, in part due to their divergent historical development – as colonist's state endeavour with military purpose (Israel) and radical experiments in opposition to mainstream society in Germany. Israeli kibbutzim became ecovillages not bottom-up, but due to regime pressures. Lotan and Ketura had to find new niches to attract tourism, income and new members. This led to a reorientation towards an ecological niche, and then due to repeated governmental pressure, to the acceptance of new members who may not have the same energy standards. The EV are both radically outside, yet conform, due to the extreme attention by a society which continues their unsustainable energy consumption as before.

Geels and Schot argue that "*Niche-innovations are carried and developed by small networks of dedicated actors, often outsiders or fringe actors act as 'incubation rooms' protecting novelties against mainstream market selection*" (2007, p. 400). This could be seen in a powerful way for EV, especially Ketura, but also for other ecovillages. These "*fringe actors*", the ecovillages, were the first to employ technologies developed by ES. In this, these tiny settlements had a disproportionate effect in bringing about a regime transition towards energy sustainability. Jackson's yin and yang combined to a powerful effect.

For future research, we suggest an in-depth exploration of the energy footprint of ecovillages' tourism industry. For energy start-ups, we propose to refine Bjornali's and Ellingsen's call for research on "*how they grow rather than how much*" (2014, p. 32) through comparative research on growth differences between

47 Interview Israeli start-up C, 5 February 2018.

48 Interview German start-up A, 22 January 2018.

49 Interview German start-up E.

50 Interview German start-up A, Interview Israeli start-up B, 6 February 2018.

51 Interview Israeli start-up C.

energy start-ups motivated by environmental concern and "*unintentionally green start-ups*" (Bergset and Fichter, 2015, p. 134).

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Learning from past and current energy transitions to build sustainable and resilient energy futures: Lessons from Ireland and The Gambia

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1. Introduction

Traditionally, energy research has mainly fallen under the remit of natural science disciplines which focus on developing technological responses to energy generation, distribution, supply and consumption challenges. As a result, energy issues have largely been considered through a technical lens within both policy and research spheres (Shove and Walker, 2014). Policy approaches emerging from this limited techno-centric development paradigm in which "*what is measured is what matters*" overlook the human dimension of energy systems change (Chambers, 2012, p. 192), consideration of which is imperative for sustainability transformations. A lack of insight into the lived experience of change as it plays out in different contexts hinders the long-term success of decision making and interventions (Bhushan and Kumar, 2012).

However, it is increasingly recognized that understanding societal dimensions is fundamental in the decarbonization of energy systems and for energy justice transformations. This is reflected in the push towards more decentralized and democratic renewable energy ownership models (e.g. Vansintjan, 2015; Schiffer, 2014; 2017), as well as a growing body of academic scholarship, including human geographical, sociological and anthropological subfields, that engage with questions concerning energy and development. Together these disciplines seek to address limitations of techno-centric approaches to offer a contextualized understanding of the dynamics of energy systems change. The emergence of new journals (e.g. Energy Research and Social Science), research networks (Energy and Society) and discipline-specific subfields signal the growth of this burgeoning field. Energy geographies, for example, has recently emerged as a rapidly growing and cross-cutting subfield of human geographical inquiry advancing contextualized research on energy transitions. A key focal point of this field is the intersection of social, economic, political and experiential dimensions of energy systems change as it plays out in diverse temporal, spatial and scalar contexts. Encompassing an increasingly diverse array of theoretical perspectives and empirical contexts, energy geographies has become a platform for varied explorations of the energy-society nexus, from the lived everyday experience of energy to the broader spatial and institutional aspects of energy systems change (Bouzarovski et al., 2017).

Complementing this, human-centred design research offers a holistic, contextualized and iterative approach to help create resilient energy futures. Here, design anthropology which is "*more oriented toward intervention and transforming social reality than traditional anthropology*" provides 'actionable' human insight which is the foundation of 'design thinking' (Otto and Smith, 2010, p. 3; Brown, 2009, p. 49). In addition, urban design provides a useful framework for mapping and analysing changes over time. Building on earlier definitions of the 'urban metabolism' (e.g. Currie and Musango, 2016; Girardet, 2008; Kennedy, Cuddihy and Engel-Yan, 2007), the concept of energy metabolism is understood as the culmination of socio-technical, socio-economic, socio-ecological and socio-political flows of resources, including electricity, transport, people, food, policies and information, in and out of, as well as within, a defined place. Together geography and design approaches offer promising potential for expanding analysis beyond the techno-centric. To this, they are particularly suited to respond to a key gap in understanding issues of power and social differentiation (e.g. gender, class, race) in the context of energy systems change.

Recently there has been a proliferation of work that compares legal frameworks and financing mechanisms across different national and regional contexts (e.g. Community Power[1]), including limited human-centred and contextual energy transitions research (e.g. Energise[2]). However, comparatively little research work compares the lived experiences of energy systems change of industrialized countries with developing nations, especially from the perspective of longer developmental trajectories. In response to these gaps, this paper discusses a collaborative international research study on energy systems change. In doing so it highlights the potential of a human-centred, contextual approach for revealing insights into hitherto overlooked contextual dimensions that shape everyday energy practices, cultures and patterns of resource use. In providing an important and timely contribution to advance understandings of overlooked contextual factors, it discusses shared and divergent themes and experiences emerging from a cross-cultural,

1 Available at: <www.communitypower.eu> [Accessed 9 March 2018].

2 Available at: <www.project-energise.eu> [Accessed 9 March 2018].

interdisciplinary comparison of an industrialized (Ireland) and developing (The Gambia) context. While a range of intersecting themes emerged as significant in the social analysis of drivers and experiences of energy transitions, this paper is limited to a discussion of three key themes as a means to illustrate the potential of a human-centred approach to energy research. The research is of direct policy relevance and can be used to inform the development of future interventions for just sustainability transitions.

In what follows, this paper provides an overview of the human-centred, contextual methods employed and introduces the research study contexts. Following this, it presents themes that emerge from the findings (Section 3) and in concluding reflects on the value of an ethnographically inspired and comparative approach to energy transitions research (Section 4).

2. Methodology

Human-centred approaches to energy transitions open up the study of energy to the wider social sciences and humanities. This area of research offers an alternative conception of sociality, one in which human behaviour is understood as intrinsically integrated into the social, economic, cultural, material, spatial and political contexts of everyday life. The recent advancement of ethnographic everyday life approaches to energy research has seen the adoption of a range of alternative methodologies. There has been a shift toward the employment of in-depth, interpretive, qualitative and biographic procedures to explore how lives, practices and contexts intersect in energy systems change.

In this study, comparative research employed human-centred design methods that combined a range of ethnographic tools, including retrospective, biographic interviewing, to understand system change over time combined with an immersive and observational methodology. In recent years, biographic methodologies have received increased attention within sustainability research as offering contextual, dynamic and human-centred approaches to researching consumption and demand (cf. Hards, 2012; Henwood et al., 2015; Greene and Rau, 2018). Biographic inquiry treats and studies individual lives as embedded within situated temporal, spatial and social locales (Elder and Giele, 1998; Blue et al., 2014). Providing "*a sophisticated stock of interpretive procedures for relating the personal and the social*" (Chamberlayne et al., 2000, p. 2), biographic methods enable the social scientist to construct a detailed contextualized understanding of social life as well as to reveal how pasts impact upon the present (West and Merrill, 2009). In this study, biographic-narrative interviewing involved constructing detailed accounts of individuals' wider biographic history and changing domestic energy practices and routines over the course of their lives.

In The Gambia, repeated immersions in the coastal community of Kartong between 2010 and 2018 have led to in-depth human insight into changes in local energy culture, predominantly focused on that time period (e.g. Schiffer, 2016). Immersions have been supported by ethnographic methods including semi-structured interviews and observation as well as mapping of infrastructure changes and participatory workshops on energy futures. These form part of a human-centred design methodology aiming to understand and influence long-term changes of the energy metabolisms. In order to facilitate cross-cultural comparisons of the intersections of lives, practices and contexts in energy systems change over longer timescales, the researchers collaborated and conducted a series of biographic semi-structured interviews with a cross-section of elders in Kartong in January 2018. These focused on the evolution of energy culture and practice since childhood.

For the purpose of this comparative investigation, the paper discusses a limited number of themes emerging from an analysis of 26 semi-structured interviews with people in Ireland and The Gambia. Participants ranged from approximately 50 to 100 years of age (in The Gambia exact ages are not always known), with a broadly equal gender representation with 14 men and 12 women. Sampling criteria sought to capture diversity among dimensions of age, gender, socio-economic status, education and geographical location.

2.1. Overview of research contexts

Ireland has experienced transformational socio-technical development over the course of the latter 20th and early 21st century, moving from a poor, primarily agrarian society to a wealthy, (post)industrial economy. Following its independence from the United Kingdom in 1922, Ireland remained a demographic and social outlier in a European context, marked by mass emigration and poverty, well into the late 20th century. However, Ireland's entry to the European Community in 1973 marked a decisive turning point for the trajectory of the nation, and, over the past fifty years, the country has witnessed rapid and dramatic socio-cultural, economic, institutional and infrastructural change. This change has been associated with rising living standards and increasing consumption, a process which has intensified during the period of economic expansion in the early 21st century known as the 'Celtic Tiger' (McDonald and Nix, 2005; EPA, 2006).

The Gambia ranks 173 on the Human Development Index. Over the past several decades the country has experienced significant development, political and economic upheaval. The Gambian community of Kartong, where this research was based, is located on the southern coast of the West African nation and has seen drastic changes in local energy culture over the past fifty years. In the past, Kartonkas relied almost exclusively on the natural environment which provided food and water in abundance. A community characterized by a circular economy has over time become increasingly exposed to globalized forces. Over time political-economic and infrastructural developments, some of which were short-lived, and access to education have contributed to changes in key social practices, including communication, procurement of food, lighting and mobility. More recently, change has accelerated through the partial connection of the settlement area to grid electricity in 2013. In the process of delivering access to modern energy services, Kartong has moved from a predominantly circular to a linear energy system that is highly dependent on imported fossil fuels, and, to a lesser extent, food products (Schiffer, 2016).

Despite a shared overall trend of development, different rates and context-specific factors characterize the two cases. To this end, a comparative contextual analysis holds much potential for revealing commonalities and differences in how energy transitions are experienced in situated times and places.

3. Findings

The in-depth analysis of changing energy cultures and practices revealed a complex web of contextual factors reconfiguring the fabric of daily life and shaping demand over time (cf. Greene, in press; Schiffer, 2016). In demonstrating the value of human-centred and contextual energy research, this section presents selected themes that have emerged from the cross-cultural ethnographic analysis of evolving energy cultures in Ireland and The Gambia. This includes institutional, political-economic and normative dimensions of energy systems change as well as the socially differentiated ways in which it is experienced.

3.1. Political-economic and infrastructural change

The biographic-narrative accounts revealed the important role of government, policy and institutions in steering demand intentionally and unintentionally. Ireland's entry to the EU was discussed by many as a crucial turning point in the country's developmental trajectory, with subsequent policies emerging that directly and indirectly shaped the population's everyday lives and resource use over time. Several individuals discussed the role of EU directives in the introduction of government policies that have shaped conduct. Broader shifts in a host of non-energy policies, relating to factors such as gender and family, economy, health, work and education, emerged as significant drivers of change in everyday practice. For example, policies such as the introduction of food labels and sell-by dates, the increasing participation of women in paid labour, as well as car-centric work policies have reshaped meanings and modes of performance. For the best part of the 20th century, gendered mobility norms and work policy structures excluded women from full participation in car driving. However, large-scale car-centric infrastructural development and changing employment structures provided a context for the recruitment of women and increasing numbers of men to driving, eventually locking individuals into unsustainable patterns of car use. It was in this context that the car has come to be understood as an essential and largely non-negotiable component of a worthwhile life. Planning policy relating to housing, roads and location of services intersected to drive increasing reliance on the car, without which many individuals felt they would be unable to accomplish social practices and access amenities necessary for everyday living (cf. Greene and Rau, 2018; Greene, in press).

Similarly, the biographic analysis of change in The Gambia highlighted the importance of political developments. Following the 1994 coup d'etat in which Yahya Jammeh seized power of the country, The Gambia underwent visible infrastructure developments. This includes the development of the country's first television station, mobile communication networks and the construction of the Kombo Coastal Road which connects Kartong to the urban areas of Brikama and Serrekunda via Gunjur. These developments significantly transformed the rhythms and possibilities of daily life. As a Kartong resident explained: Before "*it will take you 8-10 hours to travel from Brikama to Kartong [...] It was very difficult [...] From Gunjur to Kartong you don't think of a vehicle. You walk on foot*" (Schiffer, 2016). While on the one hand, the road has provided new employment opportunities and access to urban markets, on the other it has facilitated the extraction of resources including forest products and mineral sands that have had adverse effects on the local environment. The impacts of repeated sand mining in particular have been protested and in 2015 led to the widely publicized arrest of the 'Kartong 33' youth (Jadama, 2015; M'Bai, 2015). Under Jammeh, infrastructure development, which included the connection of Kartong to the electricity grid, arguably served as political propaganda to emphasize 'progress' under the regime, bringing apparently beneficial changes. However, as the example of sand mining highlights, it also opened the community up to new environmental and social risks. The longer-term impacts of the recent transition to a new government remain to be seen.

3.2. Social networks and energy culture

Across the two case studies, the biographic-narrative data revealed the intricate co-evolution of energy systems with changing patterns of social organization and personal relations. In the Irish context, the retrospective analysis highlights that the creeping technologization of daily practices was associated with the demise of a strong sharing and circular economy. Helped by an increasing availability of and access to private credit, the economic system became progressively linear, marked by individualism and closed domestic spheres. Through participants' accounts it is possible to discern the ways in which circular and linear resource economies are characterized by fundamentally different patterns of social organization and practice. In Ireland the circular, low-resource intensive economy of the past was characterized by strong relations of interdependence between households. Participants spoke of the wide-spread sharing of appliances and goods between households and highlighted the importance of familial and friendship networks in the slow and gradual accumulation of technologies in the home. This was contrasted with the instantaneousness of material access in contemporary Ireland (Greene, in press). As practices became increasingly imbued with labour-saving devices, these relations and networks evolved; social ties and sharing of material resources declined as households became increasingly disconnected and disembedded from place-based communities.

Parallel insights can be drawn from The Gambia case. Today, strong ties between extended families and friends remain in contemporary Kartong. However, as daily lives and practices are gradually becoming technologized, social values and community relations are being transformed. Many Gambian elders reflected on the relationship between socio-technological development and changing values and patterns of social relations. Specifically, many associated labour-saving and communication technologies as centrally implicated in the loss of traditional norms and values which used to guide and structure their lives. In the view of some elderly people technological development, although improving the quality of life in certain respects, had negative outcomes in eroding traditional values and approaches towards land use and the management of local environments. As one older male participant (66 years old) commented:

> "*Technology, it has made people more separate [...] it has destroyed some of the old norms and values [...] young people don't listen to them [the elders] anymore [...] small boys, young men, all they care about now*

is having money in their pocket. The respect for older values and the protection of the environment is fading out. So there is a vast difference between the past and the current."

Gambian narratives suggest a weakening of social ties over the past decades and the emergence of intergenerational tensions in relation to values and meanings about appropriate forms of conduct. The role of access to education and information through the internet was stressed by many as contributors to the distinct generational energy cultures. Similarly, in Ireland, individuals' narratives associated the creeping technologization of everyday life with a decline in traditional social bonds and relations of dependency, as domestic spheres became increasing individualised and disembedded from community contexts. However, in interpreting these accounts it is important to be cognizant of the propensity for nostalgic representations of the past to be present in individuals' accounts. In this respect, social-gerontological work has highlighted 'narratives of decline' as a common feature of older individuals' stories of social change (cf. Bennett, 2001).

3.3. Social differentiation in experiences of energy system change

The comparative analysis of Ireland and The Gambia reveals interesting insights into the socially differentiated ways in which energy systems change is experienced along dimensions such as social class, gender and geography. For example, in the context of electrification among Irish households in the mid-20th century, individuals from wealthier backgrounds reported earlier access to the electric grid and incorporated technologies more quickly into practices than others. In contrast, those from less well-off backgrounds were more likely to practice less resource-intensive lifestyles and indicated a slower pace at which technologies were incorporated into daily conduct (cf. Greene, in press). Although not always the case, interviewees in Kartong reported that wealthier households tended to adopt technologies including radios and bicycles earlier on. More recently, when the first households were connected to grid electricity in 2013, this coincided with the rainy season and Ramadan. These seasonal factors played a key role in the initial level of uptake as many households could not afford connection fees at a time associated with lower income and relatively high expenses. A household connected to the grid quickly adopted lights and gadgets such as televisions while another even within the same compound continued to rely on candle light and torches (Schiffer, 2016).

In terms of geography, electrification in both Ireland and The Gambia has followed wider global trends of rural electrification rates lagging behind urban areas, sometimes for several decades (Scott, 2017). In The Gambia, electrification is an ongoing process and areas with access suffer from frequent load shedding. However, what is less appreciated is the fact that grid infrastructure in Kartong and other communities that appear electrified on paper, does not cover large parts of the settlement area (Schiffer, 2016; Interview with Ministry of Energy, 2018).

In addition to social positioning and geography, gender emerged as a key category of social differentiation in the experience of energy systems change. In the Irish case, analyses revealed that energy systems change and the increasing technologization of daily practice has most radically altered the biographies of women. Individuals' narratives indicated that the gradual technologization of daily lives most significantly altered the temporalities and rhythms of women's daily lives, releasing their bodies from laborious chores and, in turn, allowing them to direct their time towards other activities such as education and work. In this way, energy systems change emerged as a crucial, yet often overlooked, component of wider societal dynamics in gendered relations and family structures (cf. Winther, 2008; Greene, 2018; Greene, in press). However, this is not so clear-cut, since a recent time use survey indicates that the vast majority of domestic work continues to be carried out by women (McGinnity et al., 2015).

In Kartong, gender roles remain distinct and mirror past conditions in Irish society. However, this is changing, highlighted in the reflection of an older woman (70+ years old) who compares life for girls during her childhood with present-day Kartong:

"Then for girls life was more difficult than now. Today [...] you don't physically pound your rice. You take it to the machine and the machine will pound it for you. Nowadays, young girls have the time and even go and watch

football in the evening ... [In the olden days] by the time you are done with your domestic job, it's time to sleep [...] you hardly rest [...]. Now it's quite different. People are [...] enjoying life because machine is helping women."

Technological change in reconfiguring experiences for women was stressed in this interview. In the context of the Gambian family life, marital status, which includes sharing responsibility between several (co-)wives within a compound and children whose role is also gendered from a young age, is key (Schiffer, 2016). However, one male interviewee reported that he took on typical girls' chores as a child because he had no sisters.

Until recently Gambian women were largely excluded from formal education or their access deprioritized when families faced hardships, leading to high levels of illiteracy amongst women in Kartong. Following this, women experience exclusion in terms of capitalizing on benefits associated with electricity access, such as being able to use mobile communication devices (Schiffer, 2016). Those who have attended school are more likely to have employment that takes them away from the aforementioned traditional roles including work outside of Kartong.

The centrality of women in domestic practice provides important opportunities for interventions for sustainability as recognized by Gambian capacity-building initiatives of women in the growing renewable energy sector.

4. Concluding discussion

As this paper has demonstrated, comparative, ethnographic research uncovers valuable insights into the complex dynamics of energy transitions at households and community level over time. This includes the socially differentiated ways in which change plays out over time. Cross-cultural historical and contemporary analyses of the Irish and Gambian cases reveal how dynamics in energy practices and cultures over time are deeply connected to broader intersecting institutional and political-economic changes**.** Despite two countries with distinct trajectories and levels of development, Ireland and The Gambia have represented useful contexts on which to base a comparative analysis. Their accounts indicate that the infrastructural interventions and policies of government, planning and societal institutions have played a key role in shaping and foreclosing opportunities for ways of conducting everyday practices, with major implications for energy systems. While a range of contextual forces emerged as significant in shaping the evolution of daily life, this short paper has focused only on several key dimensions, namely political-economic contexts, infrastructural change, social relations and networks and the social differentiation in the lived experience of change. In doing so it has sought to highlight the potential of a human-centred approach to energy research. However, a range of other insights and themes emerged that have not been discussed here in great depth, including a broader discussion of the ways in which developments have been shaped by wider trends and ideological influences of neoliberalism as well as transformations in normative life course pathways and patterns of biographic and spatial mobility. The findings of this investigation indicate that understanding dynamics of stability and change at a local scale is crucial for informing decision making and development interventions.

To date most research on energy transitions conducted from a longitudinal perspective focuses on technical or macro-level scales of analysis (cf. Grin et al., 2010). Comparatively less work considers the lived experience of change as it plays out over longer timescales. As the brief snapshot of findings presented in this paper suggests, an ethnographic perspective holds much potential for shedding light on ways in which lives, practices and contexts intersect in energy systems change (Walker, 2014; Greene, 2018). The authors argue that a human-centred approach to energy transitions which considers social differentiation in complex lived experiences is necessary to design more integrated, resilient and just energy futures. For example, the centrality of women in domestic practice provides important opportunities for interventions for sustainability including capacity building. It is suggested that decision makers should engage with 'ordinary' citizens to take their lived experience seriously in the design of interventions and policies and respond to the type of nuanced and experiential evidence generated through human-centred approaches to energy transitions.

Pan-European projects and research programmes tend to focus on developing world contexts. The authors argue that expanding the geographical remit further provides an important means of discerning processes of energy systems change as it intersects with social life from a more globalized perspective. Whilst acknowledging the particularities of distinct periods and places, this is important for uncovering universal logics and processes and trends of energy transitions in the context of climate justice and global resource 'hinterlands' (European Environment Agency, 2015, pp. 25-26; Catree, 2007). A particular challenge of this type of contextualized, comparative research is to secure smaller but regular amounts of funding. This is needed to build the relationships that enable ethnographic including immersive research of this kind by providing the opportunity for repeated international field work over longer periods of time and supporting cross-disciplinary collaboration. Such work would advance understanding of situated social processes implicated in energy systems change as they play out in diverse contexts and inform future policies and interventions. Another key challenge relates to the dissemination of findings from ethnographic, human-centred research to policy and decision makers that operate in a predominantly techno-centric and neoliberal context of development (Rau et al., 2017). Future research is needed to advance work to generate new empirical findings and understandings of complex social processes shaping energy transitions as well as address existing gaps in the dissemination of social science- and humanities-based energy transitions research more broadly.

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Envisaging the unintended socio-technical consequences of a transition from fossil fuel-based to electric mobility

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1. Introduction

Electric cars are currently being promoted as a solution to private mobility's long-standing dependency on oil; however, few pay attention to the unintended consequences of electromobility on society and on climate change. For example, the predicted significant reduction in transport costs may create a rebound effect which could not only lead to an increase in energy use but also to structural changes in driving behaviours, with effects on society, the built environment and, ultimately, the climate (Galvin, 2016; Font Vivanco et al., 2014). What will our society look like when private mobility is not curbed by high fuel costs, nor by organic boundaries, such as the circadian time? If electric vehicles (EVs) do not lead to changes in mobility patterns, these will increase the impact of private transportation on society and the environment (direct and indirect pollutants from use, production and waste disposal) and could possibly lead to an increase in carbon emissions depending on the electric mix (Faria et al., 2013; Bulach et al., 2018). Conversely, if they do change mobility structurally, these changes, instead of meliorating individuals' life conditions as wanted, might lead to new, unexpected sources of stress for the environment and human beings.

2. Aims and questions

Our paper poses the following questions: What unintended socio-technical consequences might result from a transition from fossil fuel-based to electric mobility, and how to investigate them?

The research design has two objectives: (1) to work out methodological and conceptual perspectives for studying unintended consequences of the transition to electromobility, and (2) to present empirical illustrations of a transition to electromobility in two selected countries: Norway, where electric cars are spreading faster than in any other country in the world (20.9% of new vehicle sales in 2017), and Poland, where the internal combustion engine is still dominant on the roads but where the government is committed to promoting a fast transition to EVs. We propose a set of questions to guide future research on unintended consequences of the transition to electromobility.

3. Conceptualization

3.1. Electromobility as a socio-technical system

Electromobility as a socio-technical system stands for a set of interconnected networks consisting of relations between human and non-human elements. Following Geels (2004, p. 897), we "*make an analytic distinction between: systems (resources, material aspects), actors involved in maintaining and changing the system, and the rules and institutions which guide actor's perceptions and activities*". Our approach is consistent with the multi-level perspective (MLP), which explains how technological transitions come about and helps to better understand the interactions between actors, innovations and environments through the categories of landscapes, regimes and niches (Geels, 2014).

We propose to theorize electromobility as a socio-technical system which is emerging from the newly established relations between four other sectors: the energy, transport, information technology (IT) and financial systems (see Figure 1). This is done by analyzing the production/circulation of four different products: energy, mobility, information and money (financial transactions). In this context, we look at electromobility as a new kind of socio-technical system which produces and circulates a new product: a new type of mobility. The interconnected networks can be created on the level of regimes and niches. We look at whether electric vehicles are bringing change to the transport sector, and how the relations between the four sectors (Figure 1) are changing. Envisioning is going to be analysed on all levels, from the niche actors' future visions driving the novelty, to the more structuralized plans, strategies and prognoses developed by the regime actors, to collective imaginaries and utopian visions being part of a socio-cultural dimension of landscapes.

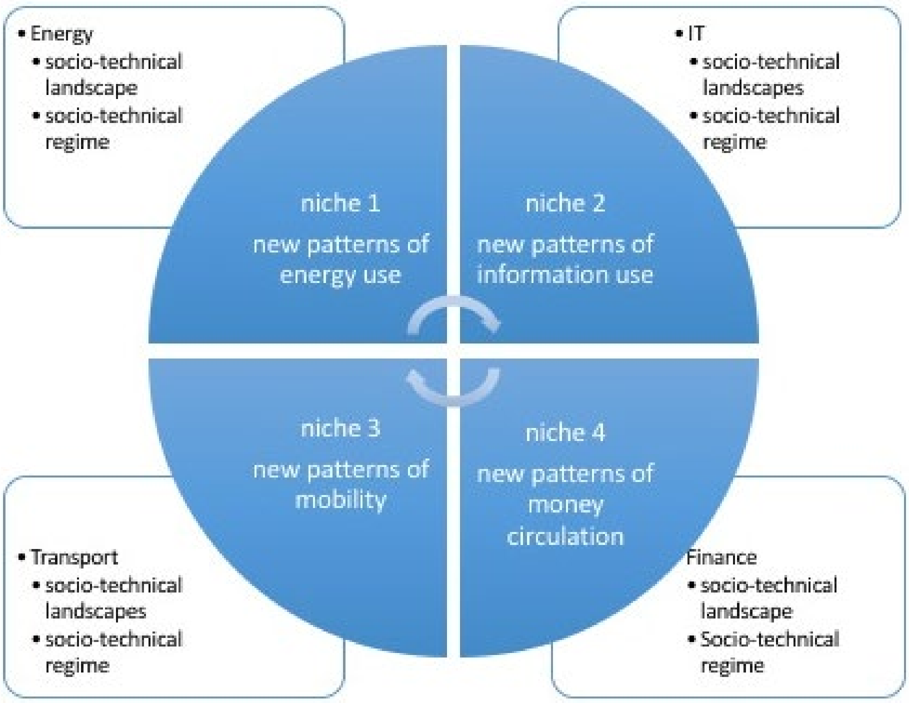

Figure 1 – Electromobility as niches in four sector systems.

3.2. Unintended consequences and visions of electromobility

Within this framework, we propose a new methodological approach to study the unintended consequences of the transition to electromobility. We conceptualize the unintended consequences as changes that have not been foreseen, expected, planned or anticipated in visions of electromobility proposed by actors[3] (both in the regimes and niches). Methodologically, we propose to search for unintended consequences resulting from the newly established relations between the four sectors and within the transport system. Our approach underlines both the importance of collective imaginaries for structuring social life, such as social expectations, anticipations and narratives about the future, as well as materialities of resources, institutions and practices. More broadly, methodologically, the project aims at proposing an interdisciplinary approach that allows bringing together social sciences: economics, sociology and science, technology and society (STS) studies as well as engineering and network theory, in order to integrate research on social and technical aspects of the transition to electromobility.

4. Research questions and hypotheses

The research questions we pose are both empirical (1, 2, 3) and conceptual/methodological (4):

1. How do future visions of regime and niche actors conceptualize electromobility? How do different social actors and different configurations of them in particular socio-technical systems imagine and conceptualize the consequences of a transition to electromobility?

3 The unintended consequences could be anticipated or unanticipated (Zwart, 2015). In this paper, we focus on unanticipated consequences of both organized and unorganized actions.

2. What institutional responses and social practices co-produce electromobility as a socio-technical system and as a particular type of socio-technical practice?

3. How do future visions of regime and niche actors conceptualize the new relations between the networks and the unintended consequences of a transition to electromobility?

4. Where and when in the socio-technical systems can the unintended consequences appear and how can we conceptualize and methodologically study them?

We propose two hypotheses to answer question (4):

1. The unintended consequences can materialize as a result of the newly established relations between the networks.

2. The unintended consequences can appear inside a network as a result of changes in relations between niches, regimes and landscapes – for example, niche activities interfere with a regime and result in its reconfiguration (see Figure 2).

5. Methodology

5.1. A qualitative framework

Methodologically, we propose to focus on new types of relations that are created in networks established between and within the four sectors, which are driven by visions of electromobility shared by various actors. We will study these new types of relations both as they are conceptualized in the visions (as intended, imagined, strived for), and as they are performed in practice (by actors, institutions, socio-technical devices). This distinction between the imagined (expressed in visions) and the practiced (by actors) will allow us to re-conceptualize the distinction between the intended and unintended, the anticipated and unanticipated consequences (proposed by Robert Merton, 1936) for the sake of studying complex socio-technical realities.

It will also allow us to propose a new methodological approach that combines discourse analysis (of visions), ethnography (study of practices) and system/network analysis (to understand the complexity of the existing and emerging systems/networks and new relations among them). Contributions from engineering studies and network theory are meant to shed new light on the quantitative side (mass, energy, money and people flows) of the system's analysis, which is often overlooked in social sciences. Critical discourse analysis theorizes imaginaries as representations of how things might or could or should be. A future vision serves as an "*imaginary which can be institutionalised and routinised as a network of practices*" (Fairclough, 2010, p. 266).

Thus, future visions have a preformative potential. We further argue that they can have a system-stabilizing function, which can be realized in various ways – from being a screen for current fears and hopes (Luhmann, 1976), to legitimization of decisions taken in the situation of uncertainty, to exporting unsolved problems or uncertainty itself beyond the assumed time horizon.

5.2. Quantitative framework

We envisage the possibility of implementing the network analysis with quantitative measures of interactions between actors within a given network and across networks. This is typically a multiplex framework (Gemmetto et al., 2016) in which every network represents a layer of a multidimensional topological object, the *multiplex (a multiple-network)*, whose interactions can be studied with the aid of null models derived from the statistical mechanics of graphs. In order to perform this analysis, we need data on national/urban level concerning financial, transport and communication interactions coupled with a simulation of the load distribution in the grid.

6. Analysis design

Research procedures are distributed between *prediction* and *action*, *cognition* and *creation*. Prediction and cognition are linked to identifying the problems, needs and desires, while action and creation are related to defining the solutions and their implementation. Envisioning is going to be analysed on all levels proposed by MLP, from the niche actors' future visions driving the novelty, to the more structuralized plans, strategies and prognoses developed by the regime actors, to collective imaginaries and utopian visions being part of a socio-cultural dimension of landscapes. Reconstructing how the future of electromobility is imagined by different actors and how it is reflected in the observed practices can help to understand the process of transforming visions into rules shaping practices.

Taking into account the MLP, we are going to focus on how systems respond to the new technological possibilities and new ideas. Each of the distinguished systems (energy, IT, finance and transport) can be described through the categories of socio-technical landscapes, regimes and niches. Actors create networks of mutual relations. The networks are changing dynamically and new relations appear both as a consequence and a cause of change made in all landscapes, regimes and niches. When analysing the future visions, we propose to focus on how communities of niche, regime and landscape actors deal with the unknown. We suggest to follow the relations between prediction (reflected in cost estimation, trend analysis, risk assessment and technological prognosis) and creation (expressed in scenarios, strategies, policies etc.) on the one hand, and relations between action (collective and individual behaviours, decisions taken, investments made by actors) and cognition (imaginaries, desires, social representations) on the other hand (see Figure 2).

Figure 2 – Dimensions of analysis: prediction (reflected in cost estimation, trend analysis, risk assessment and technological prognosis); creation (expressed in scenarios, strategies, policies etc); action (collective and individual behaviours, decisions taken, investments made by actors); cognition (imaginaries, desires, social representations).

This type of research design opens up new possibilities for identifying sites where new, unanticipated effects may appear. They can be recognized as the result of newly emerging relations of which the extremely important aspect is imagination, forecasting or planning. The investigators will bring together material aspects of the system, connections between actors and institutions, social practices and future visions (expectations, predictions, desires, imaginaries etc.). At the same time, researchers will have freedom of choice on the level of analysis, data, methods and tools. What is important is that this kind of study is designed to provoke a reasoned debate or exercise a system in dealing with the uncertainty rather than predicting or normalizing the system.

7. Poland and Norway: Different visions – different transitions

The application of the proposed research design can be illustrated by a comparative analysis of the development of electromobility in Poland and Norway. Both countries share some aspects of the landscape, such as international markets, global narratives of climate change or capitalism, but, at the same time, the socio-cultural contexts through which the landscapes are interpreted differ in the two countries. However, the socio-technical regimes and innovation niches differ and they configure different relations between the human and non-human elements. There are also some differences in the strategies of resistance and resilience of socio-technical regimes in both countries. Table 1 provides a brief introduction to further in-depth analysis. We point out the main analytical categories and some examples of possible unintended consequences.

7.1. A top-down transition to electromobility in Poland

Electric cars came onto Poland's political agenda after the change of government in 2015 and were framed by the ruling conservative party as a response to three challenges: climate change, economic development based on innovation and energy security based on domestic fossil fuels (Plan for Electromobility Development, 2017). The Polish electric car, and a broader concept of electromobility, was thus introduced by the regime actors with the objective of greening the Polish economy and making it more innovative. At the same time, electric vehicles, by increasing demand for electricity, would also increase coal consumption in the power sector, which currently accounts for up to 80% in Poland's electricity mix. In this sense, the EV is meant to become embedded in the existing regime of electricity production rather than to transform it. However, despite the idea of embedding electromobility into the regime system, Poland cannot rely on any well-developed industry, technical knowledge, regulatory or market infrastructures for the production or use of electric vehicles. It is thus rather at the level of visions, imaginaries and policy documents where electromobility is being developed, rather than in its technical or economic dimensions. The *Polish Programme for Electromobility* (2016) has been integrated into several policy areas.

On the government website[4], one can also find a reference to EU guidelines and regulations – the Plan for Electromobility Development (2017) is a response to EU activities aimed at popularizing electromobility and alternative fuels. In this sense, the Polish regime actors draw on some concepts that are circulating in the European landscape of broader climate and energy politics. The Minister of Energy is in charge of the Fund for Low Emission Transport. The fund will support the construction of infrastructure for alternative fuels and creation of a market for vehicles charged with these fuels. The annual funding amount will be around 155 million Polish Zloty, which equals about 35 million Euros. Moreover, the Plan for Electromobility Development (2017) is supposed to stimulate demand for e-vehicles. The regime actors are thus trying to create conditions for niches to develop electromobility in Poland.

4 http://www.ofvas.no/bilsalget-i-2017/category751.html [Accessed 5 March 2018].

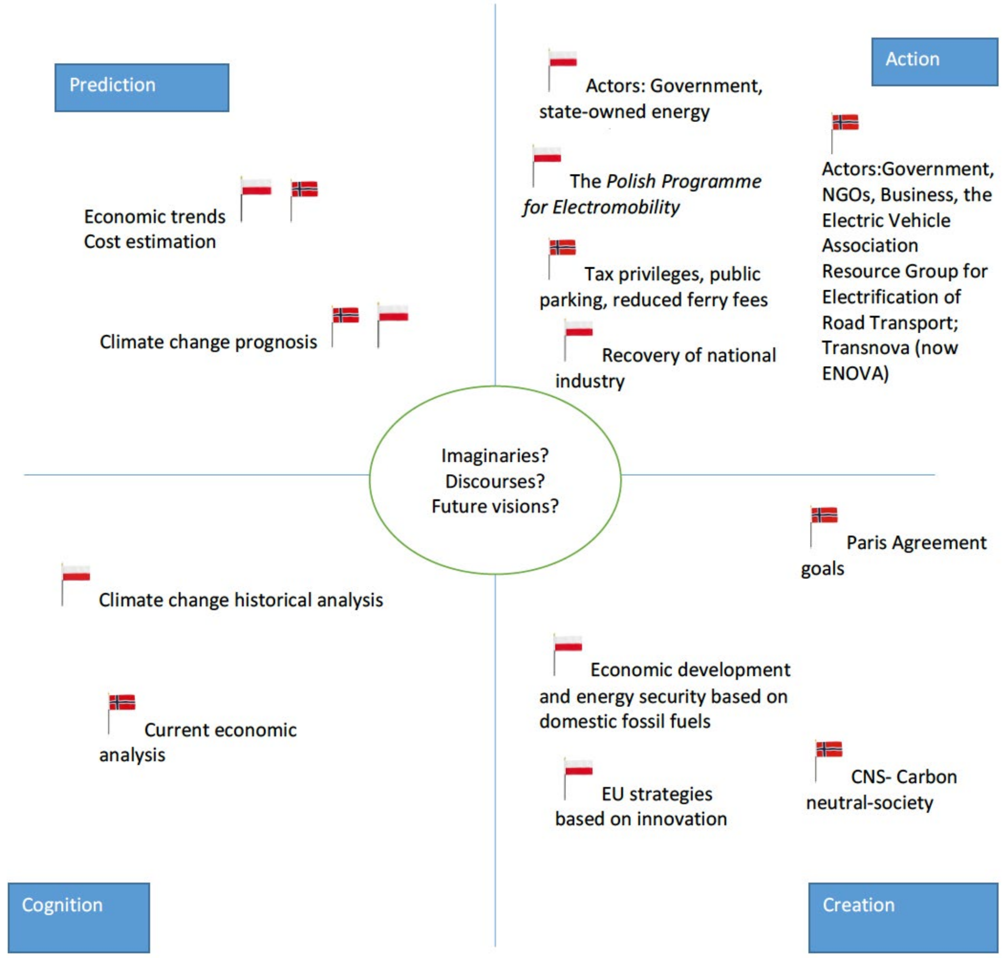

Figure 3 – Example of an analytical map.

7.2. The Norwegian case

The success of the Norwegian policy is partly explained by the fact that Norway (along with Denmark) has the highest purchase taxes on new cars in the world (see Table 1). Heavy financial incentives take the purchase cost of a battery electric vehicle (BEV) to the same level as a comparable internal combustion engine vehicle (Bjerkan et al., 2016). The reason for subsidizing e-vehicles is mainly to meet greenhouse gas (GHG) emissions reduction targets, even though business development was also important in an early phase. Policy for the promotion of e-vehicles in Norway can largely be defined as a top-down approach from the state; however, NGOs and business development have also influenced policy in Norway.

The unintended social consequences of electromobility have not been researched to a large extent in Norway. The cost of the policy, i.e. the high cost associated with tax levies and subsidies to reduce GHG emissions for society has spurred some debate, and the environmental impacts seen in global and life cycle perspectives have raised some interest (Holtsmark, 2012). However, the predominant view and policy in Norway has largely neglected this critique. Official policy documents state that the clean electricity mix in Norway as well as the ETS trading scheme will ensure that EV policy in Norway will be effective and lead to major reductions in GHG emissions. Issues such as how aggregated car ownership has been influenced by tax deductions and how low operating costs have influenced society have been overlooked. It is well possible that this might lead to increased household car ownership and use (Fridstrøm and Østli, 2016a; 2016b).

8. Unintended consequences

Table 1 – Possible unintended consequences of electromobility in Norway and Poland.

	Poland	Norway
1. Un-intended conse-quences between networks	(1) Electric vehicles, by increasing demand for electricity, would also increase coal consumption in the power sector, which currently accounts for up to 80% in Poland's electricity mix. In this sense, the greenness and cleanness of the car is put into question and the object itself is set in an ambiguous network of relations. (2) The construction of charging stations is a result of negotiations of various actors who envisage charging stations within a broader idea of electromobility in specific ways (e.g. charging stations in sites dedicated to leisure, such as moles, cinemas etc., or to work). A possible unintended consequence of this may be power grid overload in specific sites.	(1) The new national transport plan (2018-29) has set aside 536 billion NOK from 2018 to 2029 for road building and improvements, showing that road transport will be an important part of Norway's transport future, since it is probable that road improvements will increase transport volumes (Strand et al., 2009).
Common scenario *between* networks	(1) Interactions between financial and IT networks used for BEVs could reduce car ownership, with unpredictable consequences for the overall vehicle fleet. (2) IT networks used for BEVs could open the gate to new forms of hacking activity.	
2. Un-intended conse-quences within networks	(1) Expensive electric vehicles compared to cheap electricity can foster the use and increase average mileage (direct rebound effect). (2) Cheap, comfortable and environmentally friendly BEVs can increase individual mobility and, in consequence, add to the problem of huge traffic congestion in urban spaces (indirect rebound effect).	(1) There is a tendency that owners of BEVs on average have more cars than people who do not own electric cars; there is also a tendency that total GHG emissions from passenger cars are not curbed fast enough to meet GHG emissions reduction targets.
Common scenario *within* networks	BEVs could increase access to and acceptance of private mobility, curbing collective and alternative mobility (green paradox).	

9. Further recommendations

To sum up, it seems that both Polish and Norwegian policies have not taken account of unintended consequences of electromobility for society. In Poland, electromobility is still an issue for the future, the goals are declared and few examples of e-cars on Polish roads legitimize the technological promises to solve the problem of air pollution and climate change. In Norway, current trends indicate that mobility patterns in terms of driving distances have not been influenced by Norwegian EV policy: Cars drive about the same distances (Statistics Norway, 2017), and car ownership has increased. The Norwegian case points to the need to move beyond technology and support a shift from passenger cars to public transport, cycling and walking as well as to curb passenger car mobility in order to achieve major reductions in GHG emissions.

Based on the insights from this preliminary examination of the Polish and Norwegian cases, we share the concern recently expressed by other scholars in the field of social sciences (Bergman et al., 2017): This involves the risk of electromobility as a perpetuation of the status quo of a transport system based on private mobility in the long run, and legitimating inaction towards the impending air quality crises in major European cities in the short run.

Finally, the model proposed here for analysing the unintended consequences of electromobility could be readily extended to self-driving cars, which in a foreseeable future will be coupled with BEVs to shape mobility in unpredictable manners.

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The role of values in analysing energy systems: Insights from moral philosophy, institutional economics and sociology

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1. Introduction

Energy systems are currently undergoing profound transition processes towards low-carbon systems. This transition does not only include changes to technologies or infrastructures but also to rules and regulations (i.e. institutions). With climate change targets set by national governments and the international Paris Agreement, policy makers take a central role in the energy transition by changing institutions that govern energy markets. As such, we see energy systems as socio-technical systems, "*where technologies, institutional arrangements (e.g. regulation, norms), social practices and actor constellations [...] mutually depend on each other*" (Rohracher, 2008, p. 147). In addition, the energy transition is an inherently normative transition that partly comprises purposefully steered changes which are embedded in and influenced by institutional settings.

Understanding the energy transition therefore requires an institutional analysis that is capable of revealing the normative reasons behind institutional changes. An analysis of values can provide insights into these reasons because values are relatively stable underlying normative guiding principles for changes in a society (Van de Poel and Royakkers, 2011). But what role do values play exactly in the institutional changes within the energy transition? Identifying these roles offers valuable insights into factors of stability and change within energy systems, e.g. regarding acceptance, evaluation or rejection of certain technologies.

Addressing challenge B (Stability & Change), we propose a framework for institutional analysis that identifies the roles of values in institutional change. The framework builds on the Institutional Analysis and Development (IAD) framework, developed by Elinor Ostrom and colleagues (Ostrom, 2005). The IAD framework is at the core of our analysis because, firstly, it is one of the most established frameworks in institutional analysis. Secondly, it was developed to deal with socio-ecological systems that are – similar to socio-technical systems – characterized by their complex nature. To explicitly highlight the role of values for the elements of the IAD, we apply an interdisciplinary approach using conceptualizations of values from institutional economics, moral philosophy and sociology. With this approach, we contribute to academic endeavours to enrich the field of energy research with insights from the social sciences, as it is still dominated by techno-economic perspectives (Sovacool, 2014) while social-scientific research methods are underrepresented (Heinrichs et al., 2017).

Section 2 describes the concept of values and their role for institutional and technological design. Then the IAD framework is introduced in Section 3 and expanded by a value perspective in Section 4.

2. Conceptualizing values

Values are defined in a general sense as fundamental normative guiding principles for changes in a society, which are considered to be shared intersubjectively (Van de Poel and Royakkers, 2011). However, the concept of a value is used differently in various academic disciplines. We outline these different conceptualizations below and will use them later to add a value perspective to the IAD framework.

In moral philosophy, values are criteria to make statements about the ethical goodness of options for action and normative human principles worth striving for. Central questions include for example: "*How should I live my life?*" or "*What is the right thing to do in this situation?*" (Pojman, 1997, p. 12). Values are considered to be shared intersubjectively, which means values are things that different individuals can relate to and generally hold important (Taebi and Kadak, 2010; Van de Poel, 2009). In the field of ethics of technology, values are analogously used to make statements about ethical and social consequences of technologies. Typical values include health, well-being and safety (Shrader-Frechette and Westra, 1997). Central questions are "*What types of values do technological artifacts have or contribute to? How are value considerations inherent to design choices?*" (Van de Poel, 2009, p. 973). In other words, values are identifiable entities that are embedded in technologies and should be considered in design choices. They are embedded consciously and unconsciously by designers of technologies, but also emerge from the social context of the use and users of technologies (Shilton, Koepfler and Fleischmann, 2013).

In institutional economics (IE), values are seen as influencing the behaviour of economic actors and as part of formal institutions. IE broadens neoclassical economic analysis by examining institutions and trying to understand how they influence human behaviour and how they emerge (Knudsen, 1993). Decisions are not solely dependent on utility maximization, and efficiency is not the ultimate objective. Actions also depend on positive or negative impacts of more divergent values which are considered to be important in a society (Correljé et al., 2015). Values are seen as guidelines that give actors criteria for decision-making (Knudsen, 1993). Additionally, they influence the design of formal institutions (e.g. the formal rules of the game) (Correljé et al., 2015; Williamson, 1998). Formal institutions are therefore not value-free; they should endorse the values for which they were designed and might also embed values unconsciously through institutional design.

In sociology and social psychology, values are studied as principles that influence human behaviour.

> "*Values are determinants of virtually all kinds of behavior that could be called social behavior or social action, attitudes and ideology, evaluations, moral judgments and justifications of self to others, and attempts to influence others*" (Rokeach, 1973, p. 5).

Extensive theoretical and empirical work on conceptualizing and measuring values has been conducted based on the seminal contributions of researchers such as Schwartz, Bilsky and Rokeach (for reviews, see Cheng and Fleischmann, 2010; Dietz, Fitzgerald and Shwom, 2005). Schwartz (Schwartz, 1992; Schwartz and Bilsky, 1987) is known for the development of the most commonly used measurement of values, the so-called 'Schwartz Value Survey'. The survey consists of 56 items to measure individuals' value priorities, grouped in ten value types. These include orientations such as self-direction, achievement, power and universalism. Self-direction consists of values such as freedom, independence and self-respect (Schwartz, 1992).

All three conceptualizations of the concept of a value will be used as the basis to include a value perspective in our framework for institutional analysis in the discussion section. Before that, we outline the IAD framework in Section 3.

3. The Institutional Analysis and Development (IAD) framework

The IAD framework (Figure 1) developed by Elinor Ostrom and colleagues identifies important elements of socio-ecological systems and their interrelations (Ostrom, 2011). According to Ostrom (2008), institutions are defined as rules, norms and strategies that are used in repetitive situations. This definition is based on Douglass North, who states: "*Institutions are the humanly devised constraints that structure political, economic and social interaction*" (North, 1991, p. 97). They are formal and informal 'rules of the game' that shape the behaviour of actors (organizations as well as individuals). Institutions are political, social and legal rules that form the basis for activity and are needed to organize human behaviour in a structured way to stabilize the societal system (Gagliardi, 2008). In this definition, institutions do not include organizations, which are instead denoted as 'actors'.

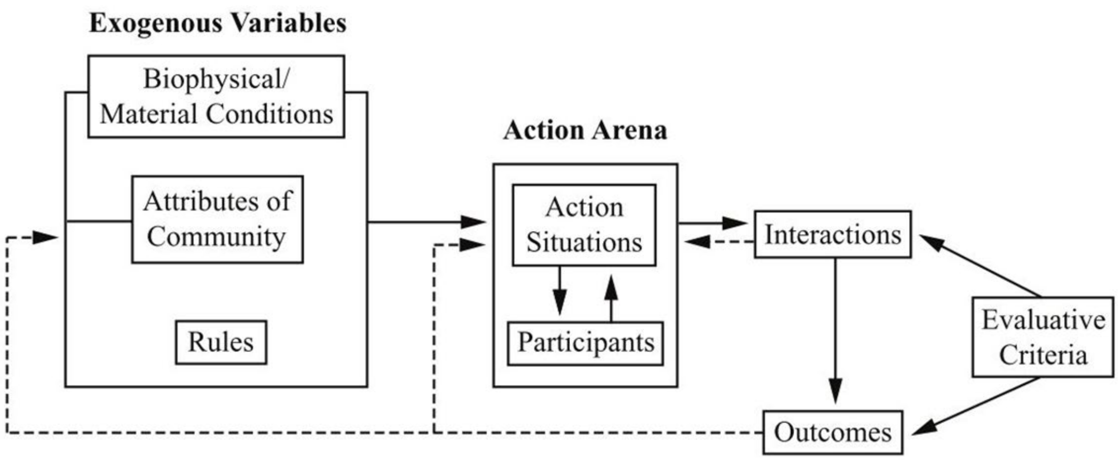

Figure 1 – IAD framework (Source: Ostrom, 2005, p. 15). Republished with permission of Princeton University Press, from Ostrom, 2005, based on data from Ostrom, Parks and Whitaker, 1974 (*Defining and Measuring Structural Variations in Interorganizational Arrangements*, Publius 4(4) Fall, pp. 87-108); permission conveyed through Copyright Clearance Center, Inc.

The IAD framework defines certain system elements that can be broadly categorized into exogenous variables, the action arena, interactions, evaluative criteria and outcomes (Figure 1). Important or decisive events are captured in the element of action situations. Action situations are thus used to analyse human behaviour within the institutional context (Ostrom, 2011). "*Action situations are the social spaces where individuals interact, exchange goods and services, solve problems, dominate one another, or fight [...]*" (Ostrom, 2011, p. 11). Based on this broad definition, action situations can be located at any level of human interaction. The decision on what constitutes an action situation and which level of aggregation is best suited highly depends on the specific case study (Pahl-Wostl et al., 2013). Using the IAD framework for an analysis of energy systems in this paper, the decarbonization of national energy systems constitutes the main coordination problem in which various action situations, such as policy and innovation processes across multiple scales, are embedded.

The participants are human actors that take part in an action situation (Ostrom, 2011). Meanwhile they are influenced by various contextual conditions, i.e. the biophysical and material context, the socio-economic conditions as well as the existing institutional setting (McGinnis, 2011). The outcome of an action situation and the processes of interaction are assessed using various evaluative criteria determined by the participants in action situations and by those observing these situations. These criteria, for example, can be questions about sustainability, distributional equity or conformance to values. This assessment can influence following action situations or the prevailing exogenous variables (Ostrom, 2011). In the following discussion, the elements of the IAD framework are explained in further detail.

4. Discussion: Adding a value perspective to the IAD framework

A consideration of underlying values requires expanding the original IAD framework. Therefore, we use the conceptualization of values in different disciplines outlined in Section 2. The following paragraphs describe the role of values in related elements of the IAD framework. The results of our analysis are summarized in Figure 2.

4.1. Participants

Since any transition process requires people taking action, our analysis starts at the element of participants. Participants can act as individuals or groups representing an entity. In contrast to the well-established formal model of the fully rational utility-maximizing 'homo oeconomicus' used in neoclassical economics, Ostrom defines participants as fallible learners that can learn from mistakes and gain more and more information over time. Meanwhile, their action choices are influenced by incentives or constraints of exogenous variables (Ostrom, 2011).

Assuming that human behaviour is driven by personal or professional characteristics and attributes – depending on the role of the participant –, the sociological and psychological definition of values can deliver important implications for actor behaviour regarding energy systems. Values work as principles influencing or driving human behaviour and are thus specific characteristics of personality (Schwartz, 1992).

For example, Perlavicuite and Steg (2015) investigated the effects of egoistic values (e.g. valuing wealth and social power) and biospheric values (e.g. valuing unity with nature and environmental protection) on evaluations of nuclear and renewable energy. They found that strong biospheric values led survey respondents to ascribe significantly more importance to the environmental consequences of nuclear and renewable energy. Additionally, the stronger respondents' biospheric values, the more negative consequences they ascribed to nuclear energy. The opposite effect was observed for renewable energy, where biospheric values were positively correlated with positive evaluations of renewable energy. Regarding the IAD framework, this implies that the participants involved in an action situation and their values can influence which technologies are discussed and how they are discussed.

4.2. Evaluative criteria for outcomes and patterns of interaction

The conceptualization of values in ethics of technology and institutional economics allows us to outline the role of values as evaluative criteria for outcomes and patterns of interactions.

Since Ostrom does not offer a detailed explanation of what outcomes can look like, we apply the broader definition of Pahl-Wostl et al. (2010), who defined three types of possible outcomes of action situations: institutions, knowledge and operational outcomes. The latter, for example, also captures the innovation of new technologies, which is of special importance for energy systems.

Speaking of new technologies, the definition of values from ethics of technology offers important implications. Values can be used to define and design essential characteristics of technologies. This is grounded in the understanding that technologies cannot be seen as neutral objects but as value-laden (Flanagan, Howe and Nissenbaum, 2008; Winner, 1980). In the same way, values can serve as design principles and characteristics of institutions. This implication, however, mostly derives from IE: values are influential for institutional change and become embedded in institutions through value judgements (Bush, 2009).

To assess the performance of a system, outcomes as well as patterns of interactions are judged by specific evaluative criteria. Ostrom mentions various types of these criteria, e.g. economic efficiency, accountability and fiscal equivalence. In the case of the energy transition, sustainability, distributional equity and consistency with other moral values are important (Ostrom, 2011). Evaluative criteria include values as they are defined in moral philosophy: goal-oriented assessment criteria and normative principles that are worth striving for and that socio-technical developments should adhere to (Shrader-Frechette and Westra, 1997).

Two examples highlight how values can serve as evaluative criteria for outcomes and interaction patterns. Firstly, if the focus of an action situation is to incentivize investment in renewable energy technologies, the outcome (i.e. the actual investment in renewables) can be assessed using values as evaluative criteria. A hypothetical region A with a high degree of small-scale solar power might be compared with region B with a focus on hydropower. Region A is likely to incorporate the values of consumer empowerment and participation in energy generation to a higher degree, while this might come at the expense of system reliability due to a higher degree of intermittent supply. Region B is likely to focus on values of emission-free, large-scale, relatively secure energy supply, while this might come at the expense of local ecosystems near hydropower dams. Secondly, and with regard to interaction patterns, the degree to which a variety of stakeholder groups is involved in decision-making processes on the siting of wind parks (i.e. the degree of procedural justice) might influence the acceptance of the wind park by local communities (Devine-Wright, 2005). This means that, depending on which level the action situation is located, the selection of actors involved will have an influence on the outcome. It will also influence the assessment to what extent core values were considered and, ultimately, whether certain technological or institutional changes are accepted or not.

4.3. Biophysical/material conditions

The biophysical/material conditions in the IAD framework describe the physical environment of an action situation (Ostrom, 2005). This includes the physical and human resources needed to produce and provide goods and services, such as capital, labour, technology, sources of finance and distribution channels (Polski and Ostrom, 1999). In our understanding of energy systems as socio-technical systems, it is important to stress that the biophysical/material conditions include the humanly devised technologies to generate, distribute and consume energy.

Research in ethics of technologies allows us to understand how values are linked to attributes of the biophysical world. Values are embedded in the technologies to generate, distribute and consume energy through the design and use of these technologies. As values are seen as design goals, engineers create technologies with the aim to incorporate specific values (Shilton, Koepfler and Fleischmann, 2013). Ethicists analyse the moral repercussions of using certain technologies and not others because technologies do not only fulfil the specific function for which they were designed but can have unintended side-effects (Barry, 2001).

To exemplify the relation between values and technologies, we look at the value implications of hydropower dams. While often considered as sustainable, because they offer emission-free energy generation, important moral repercussions include effects on the river ecosystem and distributive justice, particularly with respect to downstream water supply and the fair distribution of water along the entire length of the river.

4.4. Attributes of community

The attributes of the community in the IAD framework describe the social and cultural context of the focal action situation (McGinnis, 2011; Polski and Ostrom, 1999). Attributes that are important in affecting action situations include values or behaviour generally accepted in the community, the level of common understanding about the structure of types of action situations, the degree of homo-/heterogeneity in preferences, the size and composition of the community, and the extent of inequality of distribution of basic assets among those affected.

Although the literature on the IAD framework explicitly mentions values as important attributes of a community, insights from moral philosophy are helpful to define values in the context of a community in greater detail: Values are normative principles about what is a good and right development in a given community. They are considered to be shared intersubjectively by people within a community, which means they are things a group can relate to and generally hold important (Taebi and Kadak, 2010; Van de Poel, 2009).The degree to which a community perceives certain values to be important influences the potential outcomes that are subject to choice in an action situation and the actual outcome that participants decide upon.

An example of such shared normative principles for energy policy that need to be considered in an institutional analysis can be seen in the three focus objectives of the European Union's energy strategy and policy: security of energy supply, affordability of energy for consumers and environmental sustainability (European Commission, 2018). This was not always the case. Until approximately halfway through the first decade of the 21st century, European energy policy was dominated by a neoclassical perspective to create efficient markets. However, as policy makers increasingly recognized the threats associated with anthropogenic climate change and the need to decarbonize the energy system, the reduction of carbon emissions by moving away from the use of fossil fuels became an important goal for European policy making (Correljé et al., 2015). This shows how changing normative values can affect and broaden policy objectives considered in an action situation.

4.5. Rules

The rules in the IAD framework denote the exogenous institutional environment of the action situation. Institutions are defined as 'rules of the game' and systems of rules which enable and constrain the actor behaviour (Hodgson, 2015; Ostrom, 2005). A rule is defined as "*learned and mutually understood injunction or disposition*" for actors to act in a specific way (Hodgson, 2015, p. 7). Rules are prescriptions whether actions are required, prohibited or permitted. Importantly, the focus lies on rules-in-use, which are rules that are known to the participants in an action situation and can thus influence their behaviour. They are different from rules-in-form, which are unknown to the participants in an action situation (Ostrom, 2011). In an open and democratic society, the origin of rules can be very diverse, ranging from a group of individuals to decide on their own rules for an action situation, families and workplaces, to firms, local and regional governments, national governments and supranational organizations (Ostrom, 2011).

Values are influential for institutional change and seen as entities that are embedded in institutions (Correljé et al., 2015). Because of this, the exogenous rules-in-use shaping an action situation will embed the values for which they were previously designed. In a similar way as values are seen as embedded in technologies, rules are value-laden. Essentially, institutional economists view a change of rules as a change of value judgement by the community involved in creating rules (i.e. a change of the degree to which different values are perceived to be important and should be used as guiding principles for designing a rule) (Knudsen, 1993).

The example of European energy policy mentioned above can be extended to illustrate how values become embedded in rules. Because of the shared understanding of energy security, affordability of energy for consumers, and environmental sustainability, these three values have become the most important objectives of European energy policy. For example, as the value of environmental sustainability was operationalized by European energy policy makers in terms of reducing carbon dioxide emissions, it became embedded in the design of a range of policies, such as the European Emissions Trading Scheme and national support schemes for wind and solar power generation (Correljé et al., 2015).

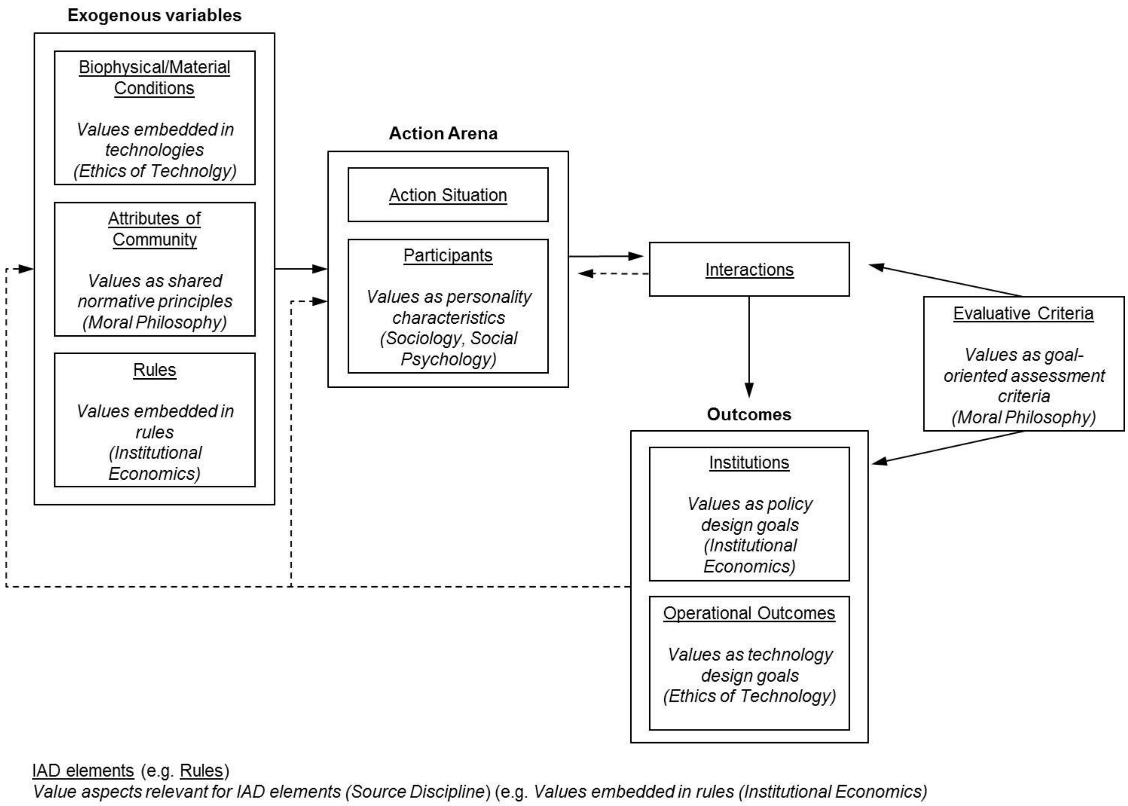

Figure 2 – IAD framework highlighting the role of values (Source: adapted by authors based on Ostrom, 2005, p. 15). Republished with permission of Princeton University Press, from Ostrom, 2005, based on data from Ostrom, Parks and Whitaker, 1974 (*Defining and Measuring Structural Variations in Interorganizational Arrangements*, Publius 4(4) Fall, pp. 87-108); permission conveyed through Copyright Clearance Center, Inc.

5. Conclusion

Using the IAD framework as basis for our framework, we expand it by a value perspective. We draw from conceptualizations and insights on values in different academic disciplines – moral philosophy, institutional economics and social psychology/sociology – to highlight the role of values for different IAD elements. Values influence the behaviour of participants in an action situation and can be used as evaluative criteria for outcomes of these situations and for patterns of interaction. They are embedded in the biophysical/material conditions as well as in the rules creating the technological and institutional environment of an action situation, and are shared principles of what is good and right in a given community. The exogenous variables are thereby related to previous action situations and in essence endogenized into the socio-technical system (Cole, 2017).

Our framework can be used by researchers and policy makers alike. Since values serve as evaluative criteria for different system designs, the framework allows cross-sectional, comparative analysis of energy systems. Our analysis can provide input for changes in the design of energy systems in different spatial contexts. It shows that a value perspective is needed when examining factors and challenges regarding stability and change in energy systems.

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Feeding back or feeding forward? A new lens into building energy use

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1. Introduction

This report reflects upon discussions and observations made by the authors during the workshop *Feeding back or feeding forward? A new lens into building energy use*, held in Bristol, UK on 15 February 2018. The purpose of the workshop was to explore two interrelated research questions:

1. What are the central research challenges in studying feedback practices?
2. What theoretical tools would improve the ability of researchers to meet these research challenges?

The workshop explored these questions by bringing together UK and Polish researchers and practitioners with expertise in building performance research, focusing on feedback practices in the domestic and non-domestic sectors. Workshop participants were drawn from a wide range of disciplinary perspectives, including architecture, sociology, environmental science, sustainability consultancy, energy behaviour and engineering. The participants were grouped in two discussion forums initially focusing on 1) building users' perspectives and 2) designers' approaches (see Table 1).

Table 1 – Overview of workshop participants

Disciplinary domain	Participant	Type of forum participation
Architecture	C	designers
Building Engineering	M	users
Environmental science	T	users
Energy behaviour	R	designers
Sustainability Consultancy	B	designers
Sociology	L	users
Institutional theory/ Architecture/Energy behaviour	S	designers

Participants were asked prior to attending the workshop to consider possible analytical benefits of theoretical approaches that could be developed to study feedback practices in the context of building performance research. These included social practice (Shove et al., 2012), institutional theory (Lounsbury et al., 2008), Gabriel Tarde's social theory on imitation (2009) and Actor Network Theory (Akrich et al., 2002), amongst others.

At the end of the two parallel forum discussions, conclusions and observations were recorded as described in detail in Section 2 below. The following subsection discusses the background and research problem pertaining to feedback practices across both empirical settings (user and designer) within the domestic and non-domestic sectors.

1.1. Background: Building performance feedback research

Feedback in the context of the built environment is viewed as a process of learning and understanding from valuable information and responses in a current building situation (Bordass and Leaman, 2005). Lessons learned from building stakeholders as well as from largely technical performance evaluations are seen in policy, practice and research as essential in improving the performance of existing buildings as well as the design, planning and programming of future buildings (Zimmerman and Martin, 2001).

The concept of feedback in the built environment was initially evidenced in the UK through the Royal Institute of British Architects' (RIBA) *Plan of Work for Design Team Operation* (1963), which introduced a *Stage M – Feedback*, where the architect returned to the building to review the success of what had been done. This was later withdrawn from the RIBA's *Architect's Appointment* (1972). While still present in principle, experience had shown that clients would seldom pay for such feedback, whilst Building Performance Evaluation (BPE) continues as a research activity with designers, constructors and clients not closely involved (Bordass and

Leaman, 2005). BPE knowledge and training is primarily practiced by academic researchers (mostly from building engineering and, more recently, the sociology community) who are not always part of the building design and delivery team (Göçer et al., 2015). A number of researchers have investigated the underlying reasons behind this (Zimmerman and Martin, 2001), documenting how the role of architects and engineers usually ends the moment occupants move into a building so that they have to rely on descriptions of user needs and behaviours instead of observing them directly (Aune, 2007).

A resurgent interest is currently observed in the use of major feedback loops because BPE is viewed as having the potential to lead to a better understanding of how we can complete feedback loops in the building design process to narrow the performance gap (Göçer et al., 2015). Building performance evaluations of both existing and new buildings across the EU have tended to reveal the at times vast difference between the predicted and actual energy use, often referred to as the performance gap (De Wilde, 2014; van Dronkelaar et al., 2016). In some EU states, buildings contribute to almost 40% of overall energy use, with developing countries within and outside the EU showing an alarming percentage growth expected with rapid global urbanization (Wang et al., 2018). Whilst some members of the research community address the problem by studying energy analysis design practices (Oliveira et al., 2017), others suggest solutions lie in more effective construction, operation and feedback of a building's energy use (Baborska-Narozny et al., 2016).

Existing literature on building performance-related feedback is skewed towards research on methods and techniques to collect and benchmark such feedback. While traditional BPE studies are generally conducted with methods such as using questionnaires, face-to-face interviews and walk-throughs, current approaches remain primarily concerned with quantifying the aspects of occupants' behaviours that are attributed to energy consumption and focus narrowly on ambient environment quality, in the context of sustainable and low energy buildings (Brown et al., 2010). Although the physical evaluation of energy performance based on measurements and tests is relatively well developed and routinized, critical analysis of occupant feedback is less developed (Chiu et al., 2014). In practice, little is known about how users and/or designers interpret and understand environmental features and systems in their buildings, and few studies have attempted to understand how occupants interact with or adapt to their environment.

Specific to the domestic sector, the evaluation of building performance has traditionally consisted of either physical monitoring or occupancy satisfaction questionnaires. Quantitative and qualitative feedback are rarely related to each other as they span across the disciplines of building science and social science (Stevenson and Leaman, 2010). With regard to non-quantitative and theoretical approaches of building performance evaluation methods, the domestic building sector appears to remain relatively undeveloped aside from the basic satisfaction surveys employed to capture user behaviour (Stevenson and Rijal, 2010). In the UK, this has been suggested to be due to a variety of factors, including the traditional disjunction between housing developers and owner-occupiers once a property is sold, which means that developers have not traditionally been interested in ascertaining how owner-occupiers are using their homes (Stevenson, 2009).

As part of addressing the lack of discussion concerning the critical analysis of (mostly) occupant feedback and in recognition of the new technologies installed in buildings which allow for real-time data feedback, new directions in establishing building performance evaluation methods to capture and interpret feedback have been the focus of a number of recent studies (Lowe et al., 2017; Coleman and Robinson, 2017; Stevenson and Rijal, 2010). These studies highlight the importance of non-technical and non-physical performance evaluation methods, focusing on 'interactive adaptivity' as introduced by Cole et al. (2008). The concept suggests how building performance could be reconceptualized to take account of context, human agency and the ongoing dialogue between the building designer, the client and the user. This approach is based on involving users and designers in the project framework, thereby taking advantage of an enhanced feedback loop with user information (Andreu and Oreszczyn, 2004; Göçer et al., 2015). Konis' (2013) research on using real-time collected data with an interactive desktop polling station and Dalton et al.'s (2013) work on using social media to explore whether it has the potential to refresh methods for BPE fall within this field.

Developing energy feedback strategies such as metering, displays, certification and billing is viewed by policy makers, businesses and practice as a key approach to changing energy use behaviour and reducing demand despite growing calls for a behavioural shift drawing on theory (Bull and Yanda, 2017; Chatterton, 2011; Schweber and Leiringer, 2012). The use of theoretical tools in the field of built environment research overall is still developing and largely overlooked (Schweber, 2015). Social practice theory appears to be currently focusing on expanding the understanding of users, comfort and energy-related issues by applying socio-technical studies investigating people's interaction with energy technologies in new and retrofitting projects (Tweed, 2013; Chiu et al., 2014; Lowe et al., 2017). Research in this field provides indications on how performance investigative methods require the underpinning of philosophical assumptions regarding the nature of our world (ontology) and the nature of warranted socio-technical knowledge (epistemology) (Lowe et al., 2017). Although it is recognized that feedback data need to be organized and managed efficiently in order to lead to effective learning, research on concepts and theoretical frameworks to study feedback practices has been largely overlooked.

The focus in energy behaviour research and energy policy has also tended to be on the end user, with little mention of how designers (architects, planners, engineers and builders amongst others) approach feedback derived from building performance studies. In addition, we know little of how those who design buildings and those who use them respond through action or inaction (similarly or differently) to any feedback strategies. What changes and what remains stable? Feedback is suggested to enable an assessment of the problem and encourage better practice and learning, but does it? How is feedback approached and actioned, if at all, by different actors who conceive a design and use its output? What logics guide the process of change and how does stability occur?

The following sections describe and discuss discussions held in the workshop that begin to explore the suitability of theoretical tools to the study of feedback practices across and within two empirical settings: the users and the designers.

2. Building users and designers – empirical issues and theoretical tools

The workshop forums explored how feedback practices have been studied (or not) in two empirical settings: with a focus on user behaviour and designers' approaches, as outlined below. After the discussion on the potential issues across the two empirical settings, the discussion reflected upon the analytical benefits of relevant theoretical approaches, as also briefly described below.

2.1. Building users – why the focus on occupants?

The discussion forum focused on how user engagement in building performance feedback is studied. Participants included experts from diverse disciplines, including participants M, T and L (as shown in Table 1). Key themes that emerged from the discussion included: (a) current understandings of user feedback in the domestic context in relation to different actors: policy, research and industry; (b) identifying key feedback questions and associated theoretical tools.

In terms of the '**policy**' perspective, discussion focused on the presentation of feedback data through metrics such as kWh, CO_2 emissions or monetary savings as potentially unhelpful to users. The discussion questioned whether quantitative feedback offered by devices such as smart meters enable long-term engagement in order to support the desired and/or expected change in terms of energy demand reduction. The designed feedback devices are all part of a 'monitoring' culture that focuses on tracking, measuring, quantifying – this may be appealing to some users only.

Considering the '**research**' community**,** discussion in the forum focused on how aims of dominant research streams are focused on behaviour change with emphasis placed on effectiveness of feedback devices such as smart meters, energy labels or environmental controls. 'Feedback' was discussed as potentially needing to be viewed as 'the independent variable', and energy use is the 'dependent one' – how does it change if one 'applies feedback'? Regarding '**industry**', discussion noted the issue of 'fragmentation' of the delivery process (see also Section 2.2).

User roles are potentially varied and dependent on the building context. The higher performing the building, the bigger the share of energy consumption in the domestic context that may be attributed to user-related factors – strengthening the role assigned to feedback. Building performance evaluation projects are capable of delivering tailored, context-specific feedback, but can this be scaled up? Potential questions/ theoretical approaches that came out of the discussion included:

Social practice theory as advocated by Shove et al. (2012) was discussed as a helpful analytical framework to the study of components of feedback practices through the following potential research questions:

- How does feedback work? What are the practices in energy-using behaviour that could be regarded as feedback?
- What is the role of feedback in energy-consuming behaviours?

Narrative/discourse analysis as suggested by Smith et al. (2017) was found to be beneficial in understanding meanings associated with feedback engagement. The following research questions were reflected upon:

- What is the meaning of engagement with the designed feedback tools?
- What stories do people tell about using their homes?

Institutional theory applied at the micro-level as noted by Lounsbury (2008) was observed to be potentially helpful in order to help explain dynamics of the feedback process as well as some of the motives and drivers for engagement. The following questions were noted:

- What is the dynamics of the building delivery process and its feedback loops?
- What is the dynamics of energy use at home – different household members, different aims? What are the motives/drivers to engage in feedback?

2.2. Building designers – broken feedback loops

The discussion forum focused on how designers engage or not in building performance feedback. Participants included experts from diverse disciplines, including participants C, R, B and S. Key themes that emerged from the discussion included: (a) understanding the effects of presentation of feedback data, (b) exploring the feedback routes (from where to where), (c) examining designers' approaches to feedback during the design process as well as after the building is occupied, (d) researching effects of broken feedback loops (see Figure 1).

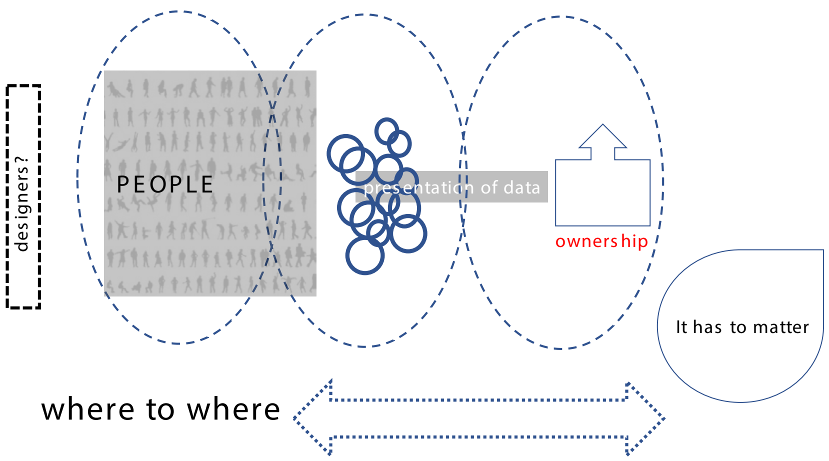

Figure 1 – Illustration of designers' broken feedback loops

Presentation and timeframe of feedback data engagement was discussed mainly in terms of designers' response to 'effects of design decisions' during design as well as certification, assessment models or evaluation during and after building handover. 'Data' was discussed as often being presented in a 'quantitative' format that is largely difficult to engage with, meaning that issues such as energy often 'drop off the agenda'. Engagement was also viewed as partially dependent on presentation of data within particular timescales – during design, construction, handover and occupation of a building. Participant C noted that (within design communities) feedback related to more than energy (incl. comfort) suggested: "*Not a lot of people care or think they don't care and assume that the absence of discomfort equates to comfort*".

Understanding what type of building information is needed at what stage of the process to enable meaningful decision making was discussed as enabling feedback. Different actors (designers, agents, clients, users) were seen as needing different types of information tailored to them.

Ownership of participation and engagement was also seen as enmeshed with feedback practices. Architects' communication with building users was discussed as depending on the types of projects as it is "*very rare to know specific information about the occupier*" (Participant B) because buildings are often speculative. Ownership is often reflected upon as dependent on people – the agents who sell buildings, building users who occupy and use buildings, clients (who may or may not be interested). Participant R noted that: "*The core principles of feedback are the ability of people to control the building*".

Feedback was discussed as layers within a **loop**. Layers of feedback – such as temporary, instantaneous, continuous within a design process, within a building, between processes and across agents – were also viewed as **people**-driven. "*There needs to be a filter between feedback and action – having feedback doesn't mean you engage*" (Participant B).

Potential questions/theoretical approaches that came out of the discussion included:

Public engagement methods as suggested by Bull and Janda (2017) were found helpful, particularly in observing the dynamics of feedback engagement throughout the design and construction process. The following questions were considered:

- How do different actors engage in feedback (designers, agents, users, clients)?
- What are the dynamics of feedback engagement? Who acts upon feedback and in what way? In design, construction and use?

Institutional theory as discussed by Lounsbury (2008) was reflected upon in relation to the study of diverse approaches to feedback as well as the shaping of meanings associated with feedback in building projects. As suggested by one of the participants (S), institutional theory is a helpful theoretical lens when studying approaches within and across organizations on particular phenomena. In institutional theory, organizations are viewed as groups that often have different goals and assumptions, draw on diverse organizing principles for an appropriate practice (Thornton et al., 2005). Participant S also noted that an analysis of the institutional logics designers draw on to legitimate, shape and justify particular approaches may be especially interesting to study (Oliveira et al., 2017). The concept of institutional logics enables a contextualization of users' engagement with phenomena within organizational and societal institutions (Friedland, 2012). The following questions were explored:

- How do designers approach feedback (logics, institutional work) during design?
- How do meanings on feedback develop in building projects (organizational cultures and processes)?
- What are the effects of no or too much feedback?

2.3. Summary

Overall, discussions focused on the dynamics of feedback, how it occurs, what makes it, who the actors are and what effects they have through their engagement (or lack of it). Presentation of feedback was discussed in both forums as a potential barrier to engagement to both designers and users. The scale and context of analysis enabled a broader discussion of the suitability of theoretical tools such as institutional theory, narrative/discourse analysis and public engagement methods.

3. Acknowledgements

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Towards a stronger integration of spatial perspectives into research on socio-technical transitions: Case studies in the Swiss energy sector and the German transport sector

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1. Introduction

This paper addresses research challenge B. It is related to the field of transition research which tries to understand and anticipate determinants and dynamics of socio-technical change. We argue that the spatial context of the diffusion of innovation needs more attention when analysing processes of institutional change in socio-technical transitions in the energy and the transport sector. Spatial variations of the relationship between stability and change should be integrated into future research programmes. There is a need for empirical, conceptual and theoretical work in this field. Furthermore, for an efficient and successful governance of transitions it is important to take spatial perspectives into account. Empirical evidence and conceptual frameworks should be developed and used as a basis for integrating spatial perspectives into policy recommendations in the context of sustainable transitions.

We use two empirical examples to demonstrate how spatial patterns matter for the development and for the governance of socio-technical transitions in the energy and the transport sector. We draw on two case studies regarding the diffusion of new technological concepts into existing regimes: the diffusion of electric mobility in Germany and the diffusion of innovation in the course of the Swiss energy transition.

2. A lack of spatial perspectives in transition research

With particular relation to large-scale infrastructure systems such as energy, transport or water supply, a transition towards more sustainability is at the top of the agenda in Europe and elsewhere. A rich body of literature on sustainable transitions of socio-technical systems has been created over the last decades. It is safe to say that in the field of transition research, the transformations of energy and transport infrastructures are among the key topics (Elzen et al., 2004; Geels et al., 2012; Kern and Smith, 2008; Schippl, Grunwald and Renn, 2017; Verbong and Loorbach, 2012; von Wirth, Gislason and Seidl, 2017). Both infrastructure systems are of utmost importance for economic growth and quality of life. But at the same time, both are responsible for serious and large-scale negative impacts on climate, the environment and human health. In both fields, a broad range of more sustainable technologies and practices are visible and some of them are already implemented. Change appears to be possible in principle. In particular, the stronger integration of renewable energies in the energy and transport sectors is considered a promising pathway to solve at least some of the problems these infrastructure systems evoke. It is therefore a crucial question how the diffusion of sustainable innovations can be further supported or even accelerated.

Transitions are accompanied by changes in the structures, cultures and practices of a socio-technical system (de Haan and Rotmans, 2011). Socio-technical changes are characterized by an interrelationship between technical, societal, economic, political and environmental factors in a specific regime adapting over time. The term 'co-evolution' can be used to describe the development of these interdependencies that may lead to new '*configurations that work*' (Rip and Kemp, 1998). Transitions are complex long-term processes that go beyond incremental innovations, requiring rather radical actions or system innovations which moreover affect the institutional settings and established behavioural routines in a sector (Grin, Rotmans and Schot, 2010). Transitions are not restricted to changes in a particular technical domain; they go beyond the simple substitution of an 'old' technology by a new one, they come along with broader dynamics of change.

The concept of the socio-technical regime is usually at the centre of transition research. Such regimes are coined by the highly institutionalized set of formal and informal rules, habits, beliefs and norms in a certain field (Fuenfschilling and Truffer, 2014; Geels, 2002). The idea of the regime proved to be able to integrate factors and actors of rather different natures into a concept of strong explanatory power. It helps to shed light on drivers of change and it helps to understand how stability can persist in highly complex socio-technical configurations. However, the spatial dimension has rather been neglected so far. Usually, regimes appear as a spatially rather homogenous conglomerate. In case of spatially highly sensitive infrastructures in particular, such as transport and (renewable) energies, such a homogenous understanding does not seem to fully exploit the potential of the regime concept. Over the last years, scholars pointed to this conceptual deficit (see Coenen, Benneworth and Truffer, 2012; Hansen and Coenen, 2015; Murphy, 2015; Van Welie et al., 2017). For example Truffer and Coenen (2012) state a lack of spatial perspectives in transition research and innovation studies.

Against this backdrop, we argue that more systematic and in-depth research and debates about the relevance of spatial factors within socio-technical transitions are needed. To illustrate and underpin this need, we draw on two empirical case studies on the diffusion of new technological concepts into existing regimes: the diffusion of electric mobility in Germany and the diffusion of innovation in the course of the Swiss energy transition.

3. Two empirical cases

3.1. Case 1: The diffusion of electric cars in Germany

With this example we illustrate commonalities and differences between urban areas and less densified areas in Germany which support or hamper the diffusion of electric mobility. The diffusion of battery electric vehicles (BEV) is an important topic in the debates about a more sustainable transport system in Germany (Schippl, 2012). But the spatial dimension is usually not well integrated in such debates. In many visions or scenarios, electric vehicles are framed as an element of highly advanced mobility systems in smart cities of the future. The concept of smart cities encompasses developments and ideas which are based on the rapidly increasing digitalization of urban processes which make cities more intelligent and at the same time more sustainable. So far it is mainly associated with larger-scale agglomeration. But interestingly, data about the first private owners of BEVs in Germany illustrate that only about 22% live in these larger urban areas which are expected to be transformed into smart cities in the future (Frenzel et al., 2015). The majority of the early adopters live in other spatial settings or even in the 'dull' countryside.

Diffusion of electric vehicles is not an isolated phenomenon but needs to be understood in the context of a region's overall transport system. Transport, in particular urban transport, is a highly complex socio-technical system which is deeply interwoven with infrastructures and the citizens' activity patterns (Schippl and Puhe, 2012). The mutual relationship between technological innovations, visions or paradigms, demand patterns and business models, also called 'co-evolution', can particularly be examined in the mobility system. Transport systems are shaped by the co-evolutionary interactions between rather different elements, such as infrastructures, technologies, political regulations, broader institutional settings and the versatile interests, preferences and attitudes of different actor groups including users (Geels et al., 2012; Truffer, Schippl and Fleischer, 2017; Puhe and Schippl, 2014). Cars are one element of these systems.

Usually, transport systems in medium-sized cities and rural areas are less densified and offer fewer transport options to their users. It is important to note that in Germany only about 30% of the population lives in cities with more than 100,000 inhabitants. A large part lives in mid-sized cities and about 27% live in rural areas with a density of less than 150 inhabitants/km^2. However, there are several important transport-related commonalities between these three different spatial categories. For example, the number of daily driven kilometres is not too different with 38 km in larger cities, 40 km in medium-sized cities and 42 km in rural areas (Infas and DLR, 2010). On the other hand, the car dependencies are higher in less densified regions. Interestingly, so far electric vehicles are relatively often used by families as a second car (Frenzel et al., 2015). The number of households with more than two persons is also higher in less densified areas than in larger cities. Another advantage of less densified areas is that more citizens have a private parking lot there, often on their own property. This facilitates the installation of private charging points.

On the other hand, the transport system is not at all static (Truffer, Schippl and Fleischer, 2017). A number of trends or dynamics are expected to change the transport system in the future, many of them actually fit with the smart city paradigm. For example, digitalization increases the attractiveness of public transport, e-bikes broaden the scope of application for cycling, e-commerce reduces the need for owning a car. Of particular interest are car-sharing schemes. They show strong growth rates in terms of usage and number of cars, mainly in larger cities. Free-floating car-sharing schemes have experienced heavy growth rates in

Germany over the last decades and in the meantime they have more registered users than the traditional station-based schemes. However, the free-floating schemes are only available in twelve large German cities, reaching about ten million people (BCS, 2018). Interestingly, about 10% of the car-sharing vehicles are electric vehicles (BCS, 2018), even if many of these still belong to pilot projects. Some of these trends are also relevant for less densified areas, but clearly to a far lesser extent. In this context it is also important to note that several studies point at a decreasing interest in car-ownership among younger adults in urban agglomerations (Puhe and Schippl, 2014). Compared to the same age group about ten or twenty years ago, this group of younger adults seems to be more open for car-sharing, for public transport and for multimodality in general.

Against this background, it seems that different socio-technical development trajectories will have to be distinguished for different spatial categories: one pathway where BEVs are mainly adopted as second or third vehicles in households with more than two persons (mainly families) in less densified areas, and a second one where BEVs are mainly embedded in car-sharing concepts in larger urban agglomerations. The first trajectory would rather be a substitution of an old technology (Internal Combustion Engines, ICE) with a new one (electric vehicles), whereas the second pathway would imply a significant change of urban mobility regimes – probably towards smart cities. In the first trajectory, the substitution of traditional ICE cars is not linked with any change in mobility behaviour and mobility patterns. It is just users buying a different kind of car. In the second trajectory a further co-evolution of BEVs with many other factors is likely, including increased car-sharing usage which means changes in mobility behaviour or mobility patterns, respectively. Apparently, the groups of early adopters are quite different in urban and in less densified areas.

It can be stated that e-cars are not entering a homogenous car regime or mobility regime. The new technology's degree of disruptiveness depends on the spatial settings. It seems likely that spatially sensitive governance strategies will be needed to take greater account of these different development trajectories.

3.2. Case 2: The early diffusion of decentralized energy systems in Switzerland

The second case study reflects spatial patterns of innovation diffusion in the course of the Swiss energy transition. Distributed energy systems (DES) on a local scale constitute a promising niche to leverage the provision of renewable energy. DES such as micro-cogeneration and multi-energy hubs integrate renewable energy sources, small-scale combined heat/power production, various energy storage methods and active demand-side management. Research on adopting these systems within existing neighbourhood contexts remains scarce, however, particularly on the role of different spatial potentials for implementation and diffusion in order to accelerate the adoption of DES.

In this work, we conceptualize new forms of DES on a local scale as socio-technical configurations (see von Wirth, Gislason and Seidl, 2017). Within the existing energy regime, these new configurations are considered as niches that might be adopted differently according to the spatial context. The DES concept is defined rather generically; hence, the concept is flexible and adaptive in terms of scale and type of integrated technologies. Our analysis is based on a mixed-methods approach. We draw upon a series of qualitative interviews with energy utilities as well as on a quantitative study of DES acceptance and early technology adoption within the German-speaking part of Switzerland. A quantitative analysis is yet to be conducted, which builds on a representative sample of n=1000 citizens who filled out a standardized online questionnaire which addressed the general acceptance of DES, its potential opportunities and challenges, perceived actor responsibilities for the energy transition and the (co-)ownership of already existing decentralized renewable energy technologies (e.g. owning a solar panel on the roof). The survey data contains the Swiss four-digit postal code, which allows for a spatial analysis in computer programmes such as Geographic Information Systems (GIS).

Findings from the series of qualitative interviews show that feasible locations for DES were found to vary according to the technologies integrated in the system. When energy conversion and storage units were part of the system, for example, the DES's adoption became a function of spatial grid convergence on the respective implementation sites. Pilot implementations in Switzerland have reported that the proximate availability of access points to the electricity, gas and local district heating grids is a highly relevant driver for the realization of each project. This grid convergence occurs in combination with specific local policy/business arrangements and knowledge/experience with DES or systems alike as key enabling conditions in the current phase of diffusion. Based on three different case study regions in Switzerland, the following context-specific adoption trajectories (may) unfold. In an inner-city neighbourhood, we found the current regime incumbents actively testing the new technology; however, also new entrants appear. For example, cooperatives start implementing and testing DES. The proximity and density of cooperative/grassroots milieus also play a role. In contrast, in the medium-sized city area, we found an energy utility identifying a first viable business model, however based on federal public seed funding for a 'lighthouse project'. The city currently enables the further development through place-making activities as an 'innovative energy location'. Thirdly, in a Swiss mountain village we see a different actor network of the local utility, farmers, house owner – coalition engaging based on a culture of aiming at 'local autarchy'.

Similar to case study 1, we intend to contribute new insights to the spatially differentiated understanding of innovation diffusion and long-term transition processes. Our findings have implications for the identification of transition pathways within the context of the Swiss energy transition. Our theoretical conclusions contribute to the current debate about capturing spatial diversity in transition thinking more accurately. We finish this explorative project phase with a set of early conclusions and hypotheses for further research:

a. Grid convergence of existing infrastructures co-defines the prioritized implementation areas due to economic feasibility despite technological adaptability.
b. Structural and regulatory barriers prevent the market entry of new actors. Yet, density of such 'new entrants milieus' plays a role locally, while 'essential learning' of these milieus happens across scales.
c. The promotion of local benefits and co-ownership leverages new entrants.
d. Early adopters and front runners make use of place making and lighthouse narratives as acceleration vehicles for niche management.
e. The adoption of DES co-evolves from an interplay of structural, geographic factors and socially constructed factors of actor relations.

4. Towards a research programme on spatial patterns in energy transitions

The two illustrative examples indicate that spatial perspectives are highly relevant for co-evolutionary dynamics in socio-technical transitions. Furthermore, a first comparative analysis reveals that spatial settings play a different role for the character, for the pace and for the destination of processes of change in the two cases. In the case of mobility, spatial differences seem to cause and accelerate differences in more urban and in more rural socio-technical regimes. Two rather different socio-technical trajectories emerge and may lead to the sedimentation of two different socio-technical configurations. It is yet no political praxis, but it is well imaginable that governance strategies explicitly use and even reinforce these differences. An example for spatially sensitive polices could be to increase the subsidies for the purchase of BEVs by private persons in less densified areas to push this development trajectory and to lower the incentives in urban areas, backed by the argument that alternatives to car usage are well available in larger cities. In contrast, the introduction of BEVs into car-sharing fleets may receive specific incentives. Furthermore, in rural areas extra incentives could be given for the installation of private charging station. There are surely other options to make use of the spatially different dynamics. So, for the first case, it can be stated that strong spatial differences are clearly visible; we may rather talk about two different regimes than about one homogenous regime. The latter holds in particular true if the concept of regimes is used to support governance strategies.

For the second case, the differences are somewhat less obvious, but they are definitely relevant. For example the relevance of place making, local identity or local autarchy seems to vary across spatial settings.

However, it seems that the spatially different 'ecosystems' for DES may be stronger integrated in the future across different spatial categories. In contrast to the first case, where electric vehicles may well be an element of co-evolutionary processes that lead to an even stronger differentiation between spatial units, in the second case processes of convergence may become more relevant.

Based on this preliminary comparative reflection we come to the following overall research question: To what extent do spatial settings cause or support convergence and differentiation in a socio-technical system such as the transport or the energy sector? A few related research questions can be drawn from the two case studies and from the preliminary comparison across cases.

Firstly, concepts and analytical frameworks are needed that help to identify the relevant factors and relations in order to describe spatially different development patterns of new niche technologies. Key factors are for example: the physical environment (incl. existing infrastructures), socio-demographic factors, institutional settings (e.g. user routines and habits) as well as actor constellations. However, it is still an open question to what extent we have similar or even generic patterns of spatial influence in the two cases. Further research is needed to answer this question. Starting points may be found in transition research literature (see for example Bridge et al., 2013; Hodson, Geels and McMeekin, 2017; Murphy, 2015; Truffer, Murphy and Raven, 2015; Truffer, Schippl and Fleischer, 2017; von Wirth, Gislason and Seidl, 2017; Van Welie et al., 2017 and others). What is needed is an appropriate concept which allows for conducting a spatially sensitive analysis of the two cases.

Secondly, related to theory building, it can be analysed to what extent spatial perspectives can be integrated into established concepts of transition research. It could be discussed which research questions and challenges emerge when integrating spatial perspectives into existing theories about the transitions of socio-technical configurations (e.g. in form of regimes and niches). For example, in which cases can or should we identify spatial variations of a regime, and at which point are we addressing two different regimes because spatial differences become too dominant? Are new concepts needed? For example, Van Welie et al. (2017) recently introduced the concept of service regimes. Furthermore, aspects of place making and local identity (Devine-Wright, 2013; Murphy, 2015), which seem to play a significant role in the second case study, could be taken into account and linked with spatially sensitive concepts of socio-technical transitions.

Thirdly, and focusing explicitly on the balance between change and stability, we could ask whether there are indicators for an ideal or favourable balance between changeability and stability. It could then be asked to what extent this balance is sensitive to spatially different settings.

Fourthly, the focus could be on the users of the new technologies. The two case studies indicate that the groups of early adopters (see Rogers, 2003) vary between spatial settings. It could be asked whether there are different views on or interests in change and stability in the field of the respective technology.

Fifthly, it is important to understand what these analyses mean for the development of governance strategies in the respective fields. Are there any general patterns that can be identified? Questions may further include, but are not limited to: In how far are the identified local context factors subject to influence (in a positive way) by local/regional stakeholders (reconsider historical case analyses)? Consequently, which factors influencing adoption shall be addressed (governed) at which geographical scales (e.g. city, canton, national, international)?

We see these five sets of research questions as key elements of a broader research agenda on spatial perspectives on sustainable transitions of large-scale infrastructure systems. Based on our analysis we further suggest making use of comparative analysis across case studies.

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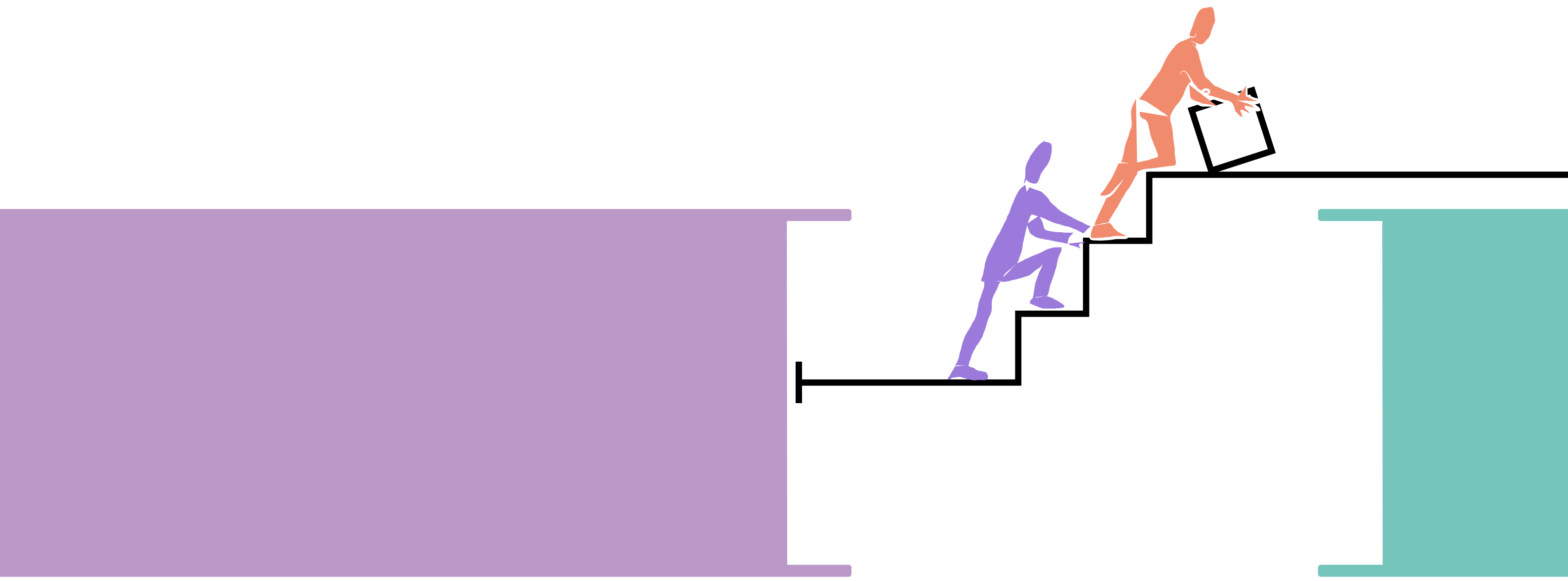

SECTION C
'Capacity-Building' in energy systems

What works for consumer engagement in the energy transition: Experimenting with a behavioural-sociological approach

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1. Introduction

Key institutions in policy making, like the European Union, have increasingly recognized the role of active consumers in the energy transition (European Commission, 2017a; 2017b; 2017c).

Engaging consumers in the transition process towards a more sustainable system is, however, not a simple matter. That is the reason why interconnections and cooperation between different disciplines from social sciences are required to identify the most effective interventions and, ultimately, inform policy design.

This project aims to i) develop a framework that combines the behavioural-economic approach with the sociological one to identify an interdisciplinary intervention that effectively engages consumers in the energy transition; ii) provide the methodological basis to quantify its efficacy; and iii) offer how-to-be evidence-based policy propositions to promote energy transitions through consumer engagement.

By engaging with the application of psychological insights to economic analysis, behavioural economics unveils a realistic picture of individual decision making: Individual preferences are not stable, but distorted by universally shared biases that the context of the moment of decision makes salient (Tversky and Kahneman, 1974). As a result, behavioural economics provides policy makers with relevant insights to influence behaviour, like increasing sustainable consumption (OECD, 2017). What behavioural economics is only recently starting to acknowledge is the central role that social context plays for behaviour, preferences and perceptions (Hoff and Stiglitz, 2016). Indeed, critical sociological inquiries have already clarified that the subjects (individual and collective) and their contexts bear an inextricable link with energy demand (Shove and Walker, 2014). Interventions that disregard the interconnections between behaviour and social context might result ineffective and questionable from an ethical standpoint and in relation to issues of energy justice (Jenkins, McCauley and Forman, 2017).

As a means to engage consumers in the betterment of energy behaviours and to let their local contexts and subjectivities play an actual role, we suggest an approach that puts them at the centre of the process. Our approach is multidisciplinary as it combines top-down approaches of behavioural economics with bottom-up and participatory approaches that are typical of critical, constructivist schools in the social sciences and that often overlap or converge with action research. Behavioural economics offers options for policy makers to influence behaviour by incorporating costless adjustments to infrastructural design (Sunstein and Thaler, 2008), such as feedback with different types of framing (Casal et al., 2017). Despite its virtues, such an approach disregards, firstly, the active role played by consumers who are unconsciously nudged to pursue the policy maker's goal, and, secondly, the dynamic influence of social context on behaviour. The practical approach of participatory energy budgeting (PEB) (Capaccioli et al., 2016; 2017) tries to solve these limitations.

This study suggests that enriching PEB with insights from behavioural economics will better stimulate consumers to engage in the energy transition. While PEB enables consumers to take part in the process of defining energy goals and to appropriate the governance of energy interventions, behavioural economics encourages consumers to engage effectively in energy-efficient behaviours.

The experimental method allows collecting rigorous evidence of the efficacy of an intervention. Therefore, we sketch a how-to-be design of a field experiment to test whether PEB enriched with behavioural insights is effective in improving consumers' engagement and energy behaviour. To better highlight the multiple beneficial facets of the proposed approach, we sketch the hypothetical application in the context of a social housing district.

2. Background and motivation

To effectively shape the energy system of the future, it is essential to push forward the availability of cleaner technologies and innovations. However, this is not sufficient. It is of utmost importance to centralize and engage those who interface with that energy system on a daily basis. As an example, equipping buildings with the most innovative energy systems might contribute to increasing energy efficiency, but what determines their ultimate efficacy is the behaviour of those who use them every day (Gillingham and Palmer, 2014). The interdependence between consumer behaviour and energy efficiency in buildings can be better addressed with a combination of different expertise (Santangelo and Tondelli, 2017).

Traditional interventions targeting inefficient behaviours, such as inefficient energy consumption, have long been informed by the assumptions that individual decision making is based on rational choice and that it can be improved by providing individuals with more information and incentives (Simon, 1955; 1957). However, behavioural economics challenges these assumptions by providing evidence that not only information, but also limited cognitive abilities, bounded willpower and consideration of others' well-being influence individual decisions (Tversky and Kahneman, 1978; Kahneman, Knetsch and Thaler, 1991). These, together with the insight that the decision context "*alters people's behavior in a predictable way*" (Sunstein and Thaler, 2008), have recently made behavioural economics a field of research instrumental to the design of more effective interventions in several policy areas (Sousa Lourenco et al., 2016) such as energy efficiency (Frederiks, Stenner and Hobman, 2015). These interventions gently push individuals to make better choices by acting on the choice context, that is by removing the contextual features that are likely to expose individuals to cognitive biases and, thus, to suboptimal decisions (Hansen, 2016).

While this novel regulatory tool contributes to delivering more effective and inexpensive policies by centralizing how individuals actually make decisions (and not how they are assumed to), it foregoes the bottom-up potentials associated with directly engaging individuals in the process of the betterment of their decisions.

The participatory bottom-up component of our framework is justified by the following interconnected reasons, which act at the pragmatic, theoretical and ethical foundations of the frame.

Firstly, it is recognized that pursuing innovation by giving at least some degree of empowerment and influence on the innovation process to the stakeholders – who are mostly concerned about the outcomes of such processes – usually improves the social acceptability of their outcome (e.g. more user-friendly, more compatible with existing conditions) and therefore enhances its impact. We recently witnessed an increasing number of diverse application domains trying to include end-users or final consumers in the design and development of their innovations: from health (Pilemalm and Timpka, 2008) to urban planning (Saad-Sulonen and Horelli, 2010), from smart grid (Throndsen and Ryghaug, 2015) to home energy management (Schoffelen et al., 2015). Secondly, it is also known that individual and collective sense of ownership towards innovation supports people in developing attachment and commitment to the success and, more importantly, the long-term sustainability of such an innovation. Among the different possible ways to foster such a sense of ownership, empowering people with the possibility to intervene in the outcome of such innovation is a valuable one (McDonnell, 2009; Abras, Maloney-Krichmar and Preece, 2004). Finally, widespread international attention has recently emerged around the ethical aspects of policy making and technological interventions. More and more consensus is building around the idea that energy justice should be pursued at procedural, distributional and recognition levels: the distribution of resources, risks and responsibilities should not be unequal; transparent, inclusive and non-discriminatory decision-making processes should be favoured; inequalities should be acknowledged when devising energy infrastructures or policies (Heffron and McCauley, 2014; Jenkins, McCauley and Forman, 2017).

3. Methodology

The PEB proposed here is grounded on the community funds model of participatory budgeting (Ganuza and Baiocchi, 2012; Sintomer, Herzberg and Röcke, 2008). It can be viewed as a democratic and participatory policy instrument for the redistribution of common funds among the members of identifiable groups (e.g. neighbourhoods, associations, citizens). Here, the common fund is directly linked with the performances of the target group with regards to a target objective. In the case of PEB, the common fund – i.e. energy budget – increases or diminishes in relation to the achievement of the predefined goals.

In practice, PEB is centred on a call for tender that is defined through public consultation with the participation of the target population and local energy institutions. Once finalized, this call for tender will allow the target population to submit requests for a part of the energy budget and to decide which ones to award (Capaccioli et al., 2016; 2017). The whole PEB process unfolds around two main phases: definition of PEB and execution of PEB. In the former, the collaborative setting of the energy goal takes place and some of the policy, or regulatory, aspects of the PEB (e.g. eligibility proposals, selection and voting procedures, criteria of transparency) are discussed and negotiated. In the latter, the formal launch of PEB initiates the submission of proposals and sets the process in motion for collection, evaluation and awarding of proposals. In short, all eligible participants can submit a request for funds, evaluate and select the most valuable one.

PEB provides the following set of tools, policy documents and guiding principles for the collective management of the energy savings that derive from improvements in energy behaviour:

Principles – similar to the original participatory budgeting (Baiocchi and Ganuza, 2014), PEB pursues the empowerment of a target group with the decision-making power over the outcomes of their efforts; it aims at creating a transparent and accountable process; it works for inclusion and democratic engagement in the process, rather than exclusion and elitism.

Policy document(s) – typically, all the regulatory aspects of PEB will be included in an official call for tender. This is usually composed of elements that govern the process at different levels. Overall, it should define and clarify (i) the energy budget and its relation to energy target achievements; (ii) the procedure and criteria for eligible requests for funds, eligible participants and eligible beneficiaries; (iii) the procedures and criteria for the evaluation and selection of winning proposals; and (iv) the awarding procedures.

Tools – a platform[1] (broadly understood) is needed for collecting, publishing and evaluating the various proposals. An outreach and communication plan will also be needed to keep participants informed about the various phases of PEB. More importantly, it is relevant to provide a tool for raising awareness of energy budget and energy performances among participants.

From a behavioural-economic perspective, the PEB feature of allowing individuals to set an energy goal constitutes a powerful behavioural lever to encourage optimal behaviours *per se*. In particular, goal setting has been depicted as an effective behaviourally-informed intervention to promote energy conservation (Abrahamse et al., 2007).

However, the added value of PEB is the participatory component to the process of deciding both the energy-saving goal and the type of activities that will be funded thanks to the achievement of that goal. This insight can be understood by referring to studies that examine how to motivate employees to perform their tasks better. These studies suggest that providing monetary incentives does not always result in changing individual behaviour. Contrariwise, individuals might change their behaviour if they derive satisfaction and enjoyment from performing their task, i.e. they are intrinsically motivated to perform that task (Ryan and Deci, 2000; Fehr and Falk, 2002). Basically, enabling individuals to have a voice in the budgeting process is exactly the means to enhance their intrinsic motivation (Shields and Shields, 1998).

Participating in the decision process does not only enhance the likelihood that the energy goals are achieved, it also enhances people's self-accomplishment and self-image perceptions: by being able to achieve the set goals, individuals feel competent with their social and physical environment (White, 1959; Bandura, 1977). Finally, not only the act of successfully achieving the set goals will make individuals value the resulting activities more (Norton, Mochon and Ariely, 2012), it will also strengthen individuals' collective identity (Kramer and Brewer, 1984) and their tendency to cooperate (Balliet, Wu and De Dreu, 2014).

To fully release the potential of effectively engaging individuals in the energy transition process, PEB can be complemented by adding insights from behavioural economics, for instance, by testing the inclusion of behaviourally-informed feedback. In fact, goal setting is especially effective in changing energy behaviour

1 This does not necessarily need to be an online or advanced platform. It can be a comprehensive webpage on an institutional website, a dedicated online content management or it can even be understood as an offline, physical platform (e.g. dedicated magazines, billboards in house buildings).

when it is combined with feedback (Becker, 1978). Feedback not only allows directing individual attention to the pursuit of the goal (McCalley, 2006), it also improves the individuals' ability to control their consumption behaviour of an invisible good, i.e. energy (Fischer, 2008).

4. A hypothetical application: A randomized control trial in a social housing district

The trial will consist of a PEB conducted in a social housing district in which a real-time monitoring system will be installed.

The aim of the trial is to investigate how providing behaviourally-informed real-time feedback can effectively engage consumers in the energy transition and, in turn, induce a more energy-efficient behaviour compared to that of the households that participate in the PEB process and receive only neutral feedback. To test the impact of such a behavioural intervention, we hypothesize to run a randomized control trial (RCT) (Harrison and List, 2004). Such an approach allows us to estimate the intervention's causal effect on consumer engagement and energy-efficient behaviour. Therefore, all households will participate in the PEB, but they will be randomly assigned to the condition 'neutral feedback' (i.e. the control group) and the condition 'behaviourally-informed feedback' (i.e. the treatment group). All households will receive real-time feedback on their energy behaviour on a touch screen display installed in their houses, making explicit how their behaviour is contributing to reach the self-set energy goals. In addition, historical household data at daily, weekly and monthly levels will be also included to facilitate households' learning of their progress in reaching the goal. The trial will run for one year.

We introduce 'negative framing' as a strategy to promote energy-efficient behaviour. In fact, when feedback includes negatively-framed information, it stimulates task attention and effectively improves behaviour (Casal et al., 2017). Moreover, when it discloses information about losses associated with consumption, it motivates people to behave in a more energy-efficient way (Asensio and Delmas, 2015), as individuals are generally loss averse (Kahneman, Knetsch and Thaler, 1991). The 'negative framing' strategy is especially interesting when the target group lives in conditions of resource scarcity: While Shah et al. (2015) show that scarcity makes individuals less susceptible to framing effects, Roux et al. (2015) provide evidence that reminders of scarcity promote acts of generosity that also allow for personal gains.

Therefore, households assigned to the control group will receive real-time feedback about how their behaviour is contributing to reach the energy-saving goal. On the other hand, those assigned to the treatment group will receive the real-time feedback framed in negative terms, which means they will receive information about how their behaviour is contributing to not reaching the energy-saving goal that will fund the activities proposed to benefit their community. The choice of conducting the trial in a social housing district is due to its social peculiarities. Individuals living in social housing districts not only face scarcity conditions (e.g. regarding budget or education), but also social segregation (Pye et al., 2015). Therefore, it is even more crucial to offer them opportunities that allow to i) improve their budget conditions by engaging in more energy-efficient behaviours; and ii) overcome social segregation by determining themselves as individuals capable of achieving valuable goals for their social and physical environment.

Here, we propose a streamlined roadmap for the PEB process. This roadmap clarifies how PEB phases can be supported by activities oriented towards the awareness of, and support and engagement for the process. Since PEB is a process that deeply integrates with pre-existing habits, social norms and local cultures, this roadmap will need to be assessed and tailored for compatibility and acceptability in the concrete contexts of the trials.

Table 1. Guidelines for the development of the PEB process and supporting activities.

PEB phases	Engagement activities	Objectives
Definition of PEB (Setting of the energy goal; PEB regulatory aspects) M1-M12	Awareness event	Preliminary dissemination event to raise awareness among residents of the forthcoming start of PEB and its relation to project trials and to launch the collaborative setting of energy goals.
	Public consultation meetings	Participants invited to discuss the setting of energy goals and the regulatory aspects of PEB (e.g. eligibility proposals, selection and voting procedures, relation energy budget and energy achievements, criteria of transparency) with institutional representatives that will be involved in the implementation.
Execution of PEB (Start of proposal submission; public voting; awarding) M13-M24	Official announcement of PEB start	Communication about commencement of PEB, directed at the interested population.
	RCT becomes active. Participants start receiving feedback	
	Sessions supporting proposal submission	Open sessions where residents/participants can receive information, clarification and support for the formulation and submission of 'requests for funds'.
	Official announcement of evaluation phase	Communication about the beginning of the evaluation phase, presentation of eligible proposals and closure of proposal submissions, directed at the interested population.
	Sessions supporting proposal evaluation and voting	Open sessions where residents/participants can receive information, clarification and support for the forthcoming evaluation and voting.
	Official announcement of winning proposal	Communication about the outcome of the evaluation process directed at the interested population. It can also be done in conjunction with a public closing event.
	Closing celebration event	Public event inviting residents and extended networks to raise awareness about the PEB experience and the project developments and to celebrate winning proposals.

5. Impact evaluation

To quantify the efficacy of PEB enriched with insights from behavioural economics on consumers' engagement in the energy transition process and, ultimately, their likelihood to achieve the energy goals, we hypothesize to exploit the quantitative and qualitative approaches.

Regarding the quantitative approach, the main observational units are given by the aggregate yearly kWhs saved by the households assigned to the control group (i.e. those who received the neutral feedback), and those saved by the households assigned to the treatment group (i.e. those who received the negatively framed feedback).

We hypothesize that the PEB, enriched with insights from behavioural economics, has a positive effect on the achievement of the energy-saving goals. In particular, reminding individuals that their behaviour is making it difficult to fund the activity that their community needs, might induce individuals to save more energy, as this will allow reaching an outcome that is beneficial to themselves and their community. Therefore, we expect the kWhs saved by households assigned to the treatment group to be higher than the kWhs saved by households assigned to the control group[2]. To measure engagement, we look at how citizens engage in the PEB process. In particular, we look at the i) number and types of proposals presented by citizens, ii) presence at support meetings, iii) presence at awareness workshops, and iv) presence at experience-exchange meetings.

The qualitative approach, carried out in the form of interviews and focus groups, will provide us with a means of control in the investigation of their engagement. In particular, it will allow us to get a hint on whether citizens use social media, online groups or the web to get information about energy-related issues. We expect households assigned to the treatment group to display higher engagement measures than those assigned to the control group.

6. Conclusions

The European Commission has summed up the need for an evidence-based approach to policy making (European Commission, 2017a). This implies that identifying what works and what can be improved is crucial for the effective engagement of consumers in the energy transition process.

To address a complex challenge like the energy transition better, a consumer engagement intervention cannot disregard how individuals actually make decisions, nor their voices and their context-specific needs. With the aim to effectively engage consumers in the energy transition process, we proposed an interdisciplinary intervention here that combines an approach based on critical sociological action research, such as PEB, with one based on behavioural economics, such as the feedback mechanism design.

To turn this proposal into practical use for energy policy makers, we sketched a hypothetical application in a social housing district and a set of methods to assess whether the proposed intervention works. This can help create a basis to make evidence more accessible to policy makers, who, in turn, can take informed decisions about potentially replicating this strategy to increase consumer engagement in energy transitions.

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2 As for any RCTs, we acknowledge the risk of facing the 'John Henry effect', i.e. participants who perceive that they are in the control group might behave more efficiently because they want to overcome the fact that they are in the control group (Cook and Campbell, 1979)

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Islands in the city? Place attachment and participation in local and non-local peer-to-peer energy trading

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1. Introduction

Electricity systems are being transformed by increases in renewable energy microgeneration systems and the deployment of smart grid mechanisms, like demand response, storage technologies and smart meters. This is enabling increased energy self-sufficiency, whether through the application of individual home systems or microgrids that can be connected to national energy grids. This new decentralized paradigm is expected to promote growth in peer-to-peer (P2P) markets and decentralized energy trading platforms, where consumers, producers and prosumers trade more directly with each other[1].

In the case of P2P energy trading markets, they can support decentralizing the energy supply and democratizing the access to electricity, often with the accompanying goals of empowering and bringing benefits to the community it is developed in (Mengelkamp et al., 2017a). While some such schemes are set up to service geographically proximate communities (e.g. the *Brooklyn Microgrid*), others cater to more spatially dispersed communities, such as the *sonnenCommunity* which connects photovoltaic/battery owners across Germany (Zhang et al., 2017). The ultimate goals of such schemes are likely to be quite different from each other (e.g. local congestion management vs. optimization of generating assets), as are people's motivations to participate in each type of scheme. In future, there is a clear potential for peer-to-peer energy trading to evolve at very different spatial scales, and the choice of scale may lead to different levels and types of participation and participants.

Unlike completely virtual peer-to-peer platforms, energy markets cannot be disassociated from the spatial reality of the grid and its physical characteristics. In the absence of network charging and regulation tailored to enable a truly transactive grid, network management challenges might arise due to multiple P2P markets operating simultaneously with different and potentially contradictory goals (Morstyn et al., 2018). For example, a national market set up to maximize solar generation and export, may at times act in opposition to a local scheme which seeks to cap exports for local congestion management reasons. The extent and nature of these challenges will be connected to the relative participation in markets at different spatial scales. In this manner, the following research questions may arise:

- How does willingness to participate in P2P energy trading differ between local and non-local markets, and what affects this?
- Which might be the impact that P2P markets have in the local grid network management, when not exclusively managed for local grid benefits?

The first question is viewed in this proposal more specifically through the lens of place attachment, or the emotional attachment people have with places (see Section 2). Much research related to place and energy infrastructure has focused on visible elements such as generation technologies (e.g. wind turbines) or high-voltage transmission lines (e.g. Devine-Wright and Batel, 2017). Local distribution networks (especially in urban areas) are different in that they are often invisible, with the cables being buried underground and substations screened off by fences or buildings. In future, people may be eligible to participate in peer-to-peer markets that may have different pricing structures, by virtue of their connection to this or that local network. To this extent, each grid is an island with an invisible coastline, part of a well-connected archipelago. Is it meaningful and sensible to search for 'local islands' in urban contexts as a way to boost P2P energy markets? Or is willingness to participate more dependent on other concerns, such as minimizing individual energy costs?

The second question relates to the grid's capacity to cope with new energy trading paradigms, such as maximizing local solar energy production, maximizing the monetization of microgeneration or being able to choose different energy suppliers at different times. Different optimization goals may have different impacts on local network management (Morstyn et al., 2018). Thus, when energy production decentralization is

1 In this document, we subsequently use the term 'peer-to-peer markets' as shorthand to encompass any model based on a trading platform that can be either direct peer-to-peer trading, or act as an aggregator of decentralized consumers, matching their offers.

realized in the name of sustainability and security of supply, which priorities can or should be implemented to guarantee the absence of blackouts and harmonization between different players/agents?

In this context, a research design addressing the previous research questions is drawn. The following sections are organized as follows: Section 2 deepens the literature review on the topic, while Section 3 defines the methods and tools to advance the research in this future low-carbon peer-to-peer energy trading transition. Section 4 advances a possible case study to validate the methodology, while in Section 5 potential applications are suggested.

2. Literature review

At the heart of the potential tension between network management for local or global benefits lies a consideration of space. All homes are connected to one or other local distribution network, and both homes and the network are effectively immovable in space. From a social perspective, space and the meanings it holds for people is described as "*place*", and the "*emotional or affective component of people's relationships with places*" is known as place attachment (Trentelman, 2009, p. 200). It is a prominent theme in energy studies which include a strong spatial element, such as on community energy projects (van Veelen and Haggett, 2017) or the siting of energy infrastructure (Devine-Wright, 2013). The role of place attachment in these contexts is nuanced; in different circumstances it can drive engagement in local activities (e.g. Doyon, 2017) and developments, be driven by it (e.g. Livingston, Bailey and Kearns, 2008) or it can act as a barrier (for example through opposition to infrastructure developments that may affect the landscape (Cotton and Devine-Wright, 2013)).

How might place attachment be associated with support for measures which could improve local grid management, such as local peer-to-peer trading? Previous research suggests that stronger place attachment is associated with increased intention to participate in "*place-protective*" behaviour (Stedman, 2002). This could suggest that place attachment would foster readiness to participate in energy trading for local benefits – if indeed people believe it to be protective of and beneficial to the local energy infrastructure. An important element of this is understanding how people view the concept of local in this context. Previous evidence suggests that place attachment may be strongest for people's homes (i.e. the building) or cities, but weaker for neighbourhoods in between them in spatial scale (Lewicka, 2010) – which is the most likely level at which local grid management would be required.

In addition to these questions around the role of place attachment in participation in local energy trading, there is also a potential tension between this and other motivations for peer-to-peer trading. While some schemes are intrinsically local, others, instead, connect communities across much larger areas such as whole countries and promote other factors such as sustainability. Rather than framing community in spatial terms (as done by Mengelkamp et al., 2017b), they instead seek to attract or define communities of interest (or communities without propinquity) (e.g. Calhoun, 1998). The *sonnenCommunity* scheme, for example, describes itself as "*a community of sonnenBatterie owners who are committed to a cleaner and fairer energy future*"[2], and sells frequency regulation services to the national grid (Stone, 2017). If we consider participation by the same generating or consuming unit in a local or national market as being mutually exclusive, and therefore the benefits (local grid management vs. national balancing) as similarly exclusive, it is important to gain insight into the factors that might affect people's choice of which market to participate in.

Such a choice may not always be an easy one for potential participants. As the debate around choices between, for example, local and organic food illustrates, it is hard to calculate which choice is better and even how to rate the outcomes to be weighed up (Edwards-Jones et al., 2008). However, it is important to understand such choices and the factors that may be associated with them because this could allow insight into which (spatial) areas might prove more or less challenging from a local grid management perspective. It could also help inform an understanding of how to frame peer-to-peer markets differently in different places or to different communities in order to maximize participation.

2 https://www.sonnenbatterie.de/en/sonnenCommunity [Accessed 25 February 2018].

It is also important in informing models of how peer-to-peer energy markets might operate. In small and isolated microgrid islands, energy modelling generally employs an economic dispatch model, ensuring secure and sustainable energy supply, while keeping the demand uncertainty levels low, by increasing the backup technologies (Neves, Silva and Connors, 2014). However, at the urban level, it is not yet clear how the existence of multiple microgrids, operating in connected or islanded mode, with distributed energy systems and different players, can operate in an integrated and cooperative way to increase renewable energy, based on smart grid technologies and services, like energy storage, demand flexibility or microgeneration, and enabling P2P energy markets (IEA-RETD, 2016). The ability to decide from whom to buy energy or from which type of energy resource empowers consumers to become more active in their choices. Thus, consumer participation takes a central role in how the P2P market and the energy model should be designed (Mengelkamp et al., 2017b, Zhang et al., 2017).

3. Methods

The proposed research uses a mixed methods design, incorporating workshops, survey experiments and energy system modelling, as described in Figure 1.

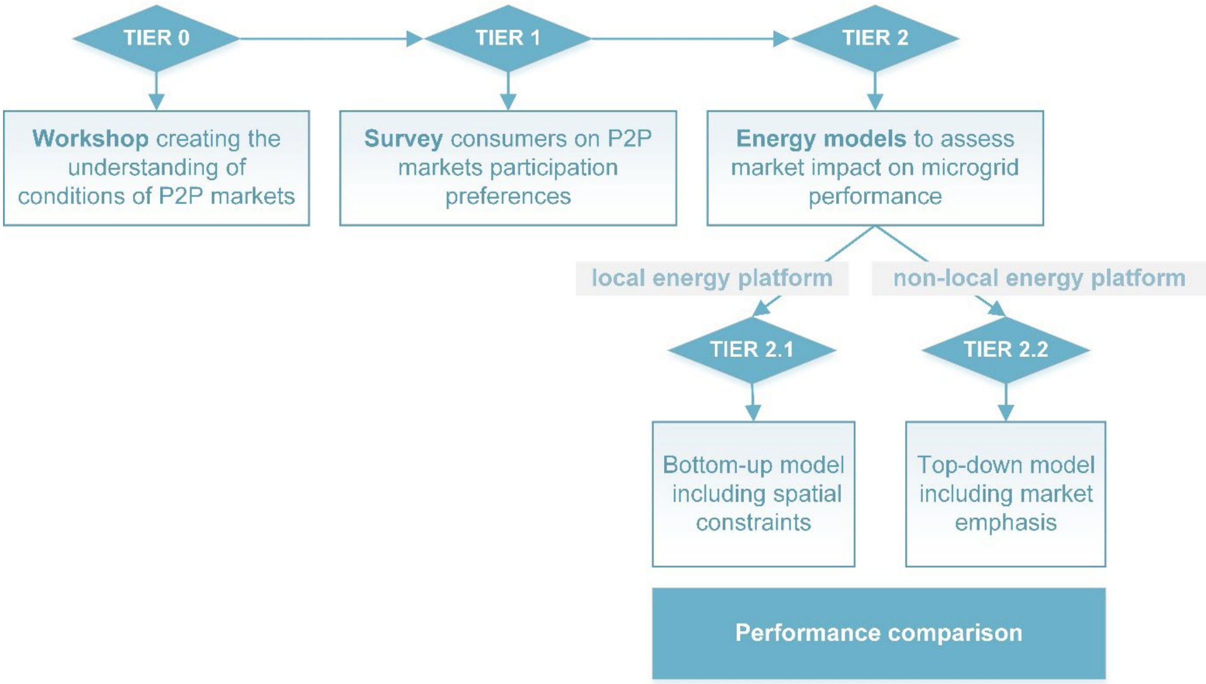

Figure 1 – Research design methodology

3.1. Tier 0: Workshop

The aim of the workshops is to explore the concept of place attachment in the context of local energy markets and to explore opinions of the proposed local benefits of such schemes, so that these can be operationalized in the survey experiment (see Tier 1). Specifically they will seek to uncover views on:

- preferences and perceived benefits and concerns around local and global network management schemes;
- the extent to which local network management efforts are perceived as place protective, and what affects this;
- differences in perceived attractiveness of schemes framed at the city or neighbourhood level, and concepts of neighbourhood and local in the context of local energy markets.

The key consideration in recruitment will be including participants with a diversity of levels of place attachment. This will be achieved by targeting participants with varying lengths of residence in a locality, which has been shown to be associated with place attachment (albeit often mediated by other factors such as number of relationships in the area) (Hernández et al., 2007). Three groups will be targeted – recent (<1 year) arrivals in the city, people who have lived in the city for some time (>5 years) but recently (<1 year) moved to a new neighbourhood, and longer-term neighbourhood residents (>10 years). Participants will be recruited with the assistance of a market research agency and will be reflective of the demographic diversity of the locality (although variables such as age are expected to be different between groups due to the likely association with length of residence). Each group will consist of approximately 8-12 participants.

The workshops will be conducted according to the following general structure:

- After ground rules and introductions, the workshops will start with a participatory mapping exercise, with participants invited to sketch a map of what they consider to be their neighbourhood including key landmarks and where the boundary lies. They will be asked to talk about and discuss why they chose to locate the boundaries where they did.
- This will be followed by an introduction to the concept of energy trading and an overview of the main goals. Three scenarios will be introduced – one operating at neighbourhood level, one at city level and the other nationally – and some key benefits highlighted (such as, in the local example, retaining money within the community). Participants will first be asked to individually note down their initial preference between scenarios (with a justification) and to note perceived benefits and concerns around each on cards. They will then be invited to discuss and reflect on each other's preferences. Particular focus will be placed on how benefits/disadvantages are perceived differently between the scenarios.
- Participants will be asked to consider whether their own conceptions of neighbourhood (elicited earlier in the workshop) align with that set out in the relevant scenario and think about the extent to which they view the different scenarios as being 'local' to them, and why.
- Any key benefits or disadvantages that are not raised by the participants will be introduced at a later stage by the facilitator. In particular they will be asked to reflect on the extent to which they believe each scenario has genuine potential to result in the claimed benefits and what affects this belief.
- Participants will finally be invited to put forward any questions and suggestions they have relating to the scenarios.

All discussions and written material will be recorded and subject to thematic analysis through coding the data and identifying themes (Braun and Clarke, 2006).

3.2. Tier 1: Survey

The second stage of the research will employ survey experiments to compare intended participation in local/non-local and environmental/non-environmental framing of peer-to-peer and decentralized energy trading markets. The sample (of approximately 2,000 individuals) will be composed of energy bill payers and be representative of a city of interest. A *2x2* between-subjects experimental design will be employed, with random groups shown an advert to participate in a basic peer-to-peer market scenario. All scenarios will highlight potential cost savings (in concrete terms), but will differ between groups with the following framings:

- emphasizing local network management benefits;
- emphasizing carbon reduction benefits (with no explicit local element);
- emphasizing both local and carbon benefits;
- emphasizing neither of the above.

Participants will be asked to indicate their interest in finding out more about the offering, participating as a consumer and/or as a supplier. A series of manipulation check items will be included. Next, participants will be asked to respond to scales designed to measure place attachment (Lewicka, 2010) and pro-environmental attitudes (Dunlap et al., 2000). Finally, potentially observable characteristics such as housing type, tenure, duration of residence, etc. will be requested, as well as information on appliance/generation/storage ownership and basic socio-demographic variables.

An initial set of logistic regression models will be constructed with dependent variables being interest in finding out more or participating as consumer/supplier, and independent variables being experimental condition (dummies for local/carbon/interaction), place attachment, pro-environmental attitudes, observable building-related characteristics and socio-demographic variables. Further regression models will be constructed with place attachment and pro-environmental attitudes as dependent variables to determine the extent to which these variables are associated with the measured observable characteristics.

Combined with knowledge of the spatial distribution of observable grid characteristics across a city, the findings will give insight into how participation, in local versus non-local, might itself be distributed, anticipating any grid constraints problems and thereby informing the modelling stage of the work.

3.3. Tier 2: Energy modelling

The modelling of P2P energy markets should include different scales of consumer participation, being informed mainly by two participation scenarios: islanded or local P2P energy market versus non-local/decentralized energy trading. At both levels, the energy modelling should define a set of control parameters which will help to understand better the nature of the problem, but should also assess key performance indicators to evaluate the performance of the solution. The first will act as constraints, while the latter are directly related to the goal of the optimization problem. Consequently, to design an energy model of P2P energy trading, the following steps are necessary:

- define the spatial scale: connected or not with the consumer attachment scale; can be a neighbourhood, a university campus, or can be a city or a region, within urban or rural contexts; different types of consumers and suppliers can co-exist; the spatial scale can/will depend on the attachment feeling of the consumers informed by the workshop and survey findings;
- map grid infrastructure and introduce it as a constraint, since the energy flux, especially at local level, is constrained by existing distribution grids;
- type of energy contract: contract with a retailer – either a local retailer or a traditional centralized retailer, or a fully peer-to-peer contract through a decentralized trading platform established according to energy needs;
- state the optimization goal and choose the key performance indicators: either in terms of economic, energy, environment or social participation point of view, or a combination, for example:
    - maximize renewable generation within the P2P market;
    - minimize energy costs for the consumers (with side effects for welfare);
    - measure the financial impact of local and/or decentralized market-based platform, so as to maximize the profits of prosumers;
    - improve access to electricity by minimizing grid related problems, such as congestion;
    - increase efficiency of distribution, such as by decreasing energy losses;
    - increase the consumers' contribution for social benefits.

To measure the impact on grid management of local vs. non-local energy markets, two scenarios should be compared, both using the same time scale. In this way, a combination of bottom-up and top-down models should be used: on one side, the energy model of Tier 2.1 should reflect the physical constraints of the grid infrastructure and demand and supply matching, while Tier 2.2, given its non-local and decentralized nature, has to be built on a top-down perspective from the trading platform. Both must be compared regarding the same optimization goals. These two strategies are schematically presented in Figure 2:

- Tier 2.1: implementing a local P2P market on a small community, functioning as an island in a urban context (left side) – this can be a neighbourhood where there might be different types of consumers, prosumers and an energy production facility owned or not by the community; assess willingness to participate in such a market and assess the market's performance against KPIs;
- Tier 2.2: Implementing a non-local P2P market based on a platform, such as *sonnenCommunity* (right side) – without constraints of consumer location, directed to different types of consumers, producers and prosumers.

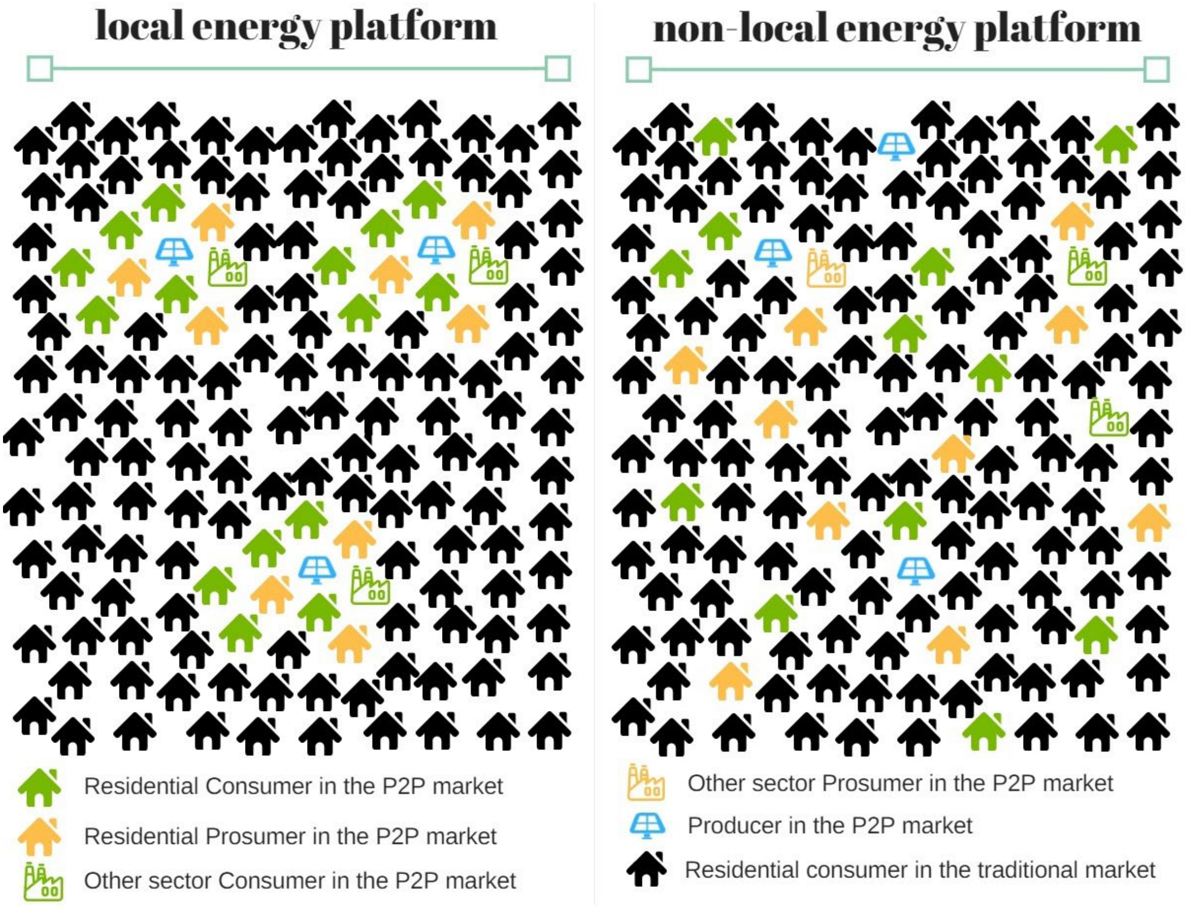

Figure 2 – Schematic representation of Tier 2.1 (left) and Tier 2.2 (right)

The modelling will also take into account whether the platform also owns or controls generation assets, which is expected to be more likely in the case of a local scheme (such as a community energy project) than in non-local markets where the aggregation platform provides only the means of connection of different agents (consumers, producers and prosumers). Also the modelling of the local P2P market should account for the possibility of a set of proximate microgrids connected with each other, using a high time scale to be able to assess grid operation (preferably with time steps of 15 min or less). The non-local P2P market model only considers the different consumers (geographically widespread) as general points of demand and/or supply as it is difficult to assess the impact of energy trading on grid infrastructure at higher spatial scales.

4. Case study cities

The previous sections have set out a range of methods that could be used in a variety of contexts to address the research questions. This section describes and justifies a specific operationalization of the approach in two case study cities: Lisbon and London. These cities are different in key ways that will contribute to the international generalizability of the findings, while also sufficiently similar to allow for meaningful comparison. Both are large metropolitan capitals of EU countries and are subject to common EU energy regulation. However, they differ in terms of solar energy potential (with Lisbon receiving almost 50% higher insolation on average[3]) and in size of economy, with the UK's GDP per capita (as a proxy of individual investment potential) being approximately twice that of Portugal[4].

For the workshops and surveys, participants will be recruited from central and suburban areas with the assistance of market research agencies. The energy modelling stage will reflect the characteristics of local grids in these cities, but will not be based on actual neighbourhoods (to maximize generalizability). The actual offerings will be based on existing projects or products such as the *Brooklyn Microgrid* (Tier 2.1), or *sonnenCommunity* (Tier 2.2). Of course, other case studies can be proposed, but the idea of completing the research design advancing an implementation assists in having a starting point for a future and effective modelling of the research problem, in order to validate the methodology. In the end, a comparison between findings in both case studies should be taken.

5. Outputs and applications

The project would deliver the following key outputs:

- a dataset and estimate of willingness to participate in local/non-local energy trading and association between this and place attachment, pro-environmental attitudes and observable building-related and socio-demographic characteristics;
- a model and estimate of the local grid management impacts associated with different levels of participation in local/non-local energy markets;
- a record and qualitative interpretation of key perceived benefits and concerns connected with local/non-local energy trading.

These may be expected to enable further work including:

- combining spatial data on local grid constraints and propensity to participate in local energy trading (based on observable characteristics) to inform estimates of locations of greatest potential/challenge, and targeting of pilots and trials;
- analysis of potential for inequitable distribution of benefits of participation in local/non-local energy trading.

6. Acknowledgements

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3 http://solarelectricityhandbook.com/solar-irradiance.html [Accessed 8 March 2018].

4 https://data.worldbank.org/indicator/NY.GDP.PCAP.CD [Accessed 8 March 2018].

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Beyond the average consumer: Exploring the potential to increase the activity of consumers in load-shifting behaviours by means of tailor-made solutions

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1. Introduction: Our look at the challenge

Challenge C is looking at the role of the consumer in future energy systems, in particular regarding demand-side management (DSM) and the potential of load-shifting actions.

The challenge views the role of 'prosumers' and 'energy citizens' as that of 'average consumers'. However, our proposal, which is based on our previous review (Shipworth et al., 2016), argues that in fact it is not enough to understand the average consumer. On the contrary, we need to understand individual preferences and constraints of consumers to ensure effective design of and interaction with future energy systems. We will look at the challenge through the lenses of differential psychology and building science to take into account that it is people and their individual characteristics and the characteristics of the energy system and buildings that will determine any interactions. We will in particular focus on applying DSM to temperature regulation in buildings given the importance of space heating and cooling for energy consumption and, especially in the context of increasing electrification, for grid stability.

The energy system will see huge transformations in the next years. There is a push towards decarbonization to keep global warming within certain bounds (United Nations Convention for Climate Change, 2018) of which the electrification of energy is an essential part in many countries (European Commision, 2018). The EU Renewable Energy Directive establishes that 20% of total energy in the EU needs to be met by renewables by 2020. Whilst not being the largest, the intermittent renewable technologies of wind and solar are growing rapidly (Eurostat, 2018b). Intermittent means that they are not available at any time (except if there was a viable way of storing the generated electricity). Hence, in order to match the supply, we need to shift electricity demand in time. Shifting demand is also crucial to prevent an overload of the electricity network, which could result in power cuts. Attempts at moving demand in time are called demand-side management (DSM) whereby consumers are incentivized or educated to use electricity at different points in time and/or whereby smart technology shifts energy use automatically (for an overview of demand response experience in Europe, see Torriti, Hassan and Leach, 2010). Likely DSM options include direct load control with and without override option, whereby a utility can directly impact on energy usage in the home, for example by turning down the thermostat at times of high electricity demand. A voluntary load reduction program might be implemented through time of use tariffs whereby electricity costs increase at times of high demand and decrease during times of low demand. The responsibility is then on the customer to change behaviour in line with price signals.

We will first provide greater detail on people and energy in buildings from the lenses of our disciplines (Section 2), before describing our research question and objectives, commonly used methods, and the individual steps and methods we would take in addressing the research question.

2. People and energy in buildings

In the EU, buildings are responsible for 40% of total energy consumption and 36% of carbon emissions (European Commission, 2018). There is a lot of unexplained variance in building energy consumption, with recent research able to explain about 40% of it (Huebner et al., 2015) to which building factors contribute the largest share. However, this does not mean that occupants do not matter – in very similar buildings, the variability in consumption is mainly due to occupants (Andersen, 2012). This makes intuitive sense – if occupants aim at realizing the same air temperature in a very large building with an inefficient heating system and in a small, well-insulated flat, the energy consumption will be hugely different. However, in very similar buildings, occupants' preferences and behaviours will exert a much greater influence since there is basically no building variability. Space heating and cooling are the largest drivers of energy and power and offer the greatest potential for load shifting. They are inextricably linked to thermal comfort, i.e. if we feel too warm, too cold, or just right in our environment. Likely load-shifting scenarios in buildings would be to change temperature settings to reduce energy/power during specific time intervals, which could compromise occupants' thermal comfort.

2.1. The lens of psychology

Psychology is defined as the scientific study of the mind and how it dictates and influences our behaviour (British Psychological Society, 2018). It explores a range of mental processes, such as perception, attention, emotion, motivation and intelligence, and uses empirical methods in its studies.

Despite the general focus on mental processes, psychology has distinct subdisciplines that have very different foci, such as occupational psychology, developmental psychology and cognitive psychology. The subdiscipline of differential psychology, also called personality psychology, is concerned with how individuals differ in their behaviour and what processes underlie those differences.

Applying psychology in general to the theme of future design and interaction with the energy system means that we need to understand the human in the system. Therefore, we need to find answers to questions such as what motivates consumers to take up novel product offers such as time-of-use tariffs, how to ensure participation in local energy markets, what kind of rewards to offer and how to frame any information given. Environmental psychology addresses such questions.

Applying differential psychology means that we need to understand individual needs, concerns and preferences related to the energy system. Given that we already know about large heterogeneity amongst consumers, looking at the challenge through the eyes of differential psychology makes greatest sense in order to arrive at tailored product offerings.

2.1.1. *What factors does differential psychology consider?*

Factors typically studied in differential psychology are intelligence and personality.

Building on Spearman's work, who first postulated that there was a general intelligence factor (g) (Spearman, 1904), it is now generally accepted that there is such a construct which includes abilities such as acquiring knowledge, abstract thinking and reasoning, adapting to new situations and benefitting from instructions (Gottfredson, 1997). In addition to agreement that g exists, there are various suggestions of whether there are also specific forms of intelligence. Sternberg e.g. postulated a triarchic theory of intelligence, which encompasses analytical intelligence, creative intelligence and practical intelligence (Sternberg, 1985).

The most influential theory on personality traits is the Big Five model that contains the five traits openness to experience, conscientiousness, extraversion, agreeableness and neuroticism (Goldberg, 1990). These traits are found across cultures (McCrae and Costa, 1997) and are relatively stable across a person's lifetime (Costa and McCrae, 1992). Openness to experience indicates the degree of curiosity, creativity and interest in novelty and change a person has. Conscientiousness refers to how organized, dependable and self-disciplined someone is. Extraversion is related to assertiveness, sociability and talkativeness. Agreeableness refers to the tendency to be compassionate and cooperative. Finally, neuroticism indicates the tendency to experience unpleasant emotions easily, such as anger, anxiety and vulnerability.

Both intelligence and personality traits have been shown to have predictive validity; intelligence for job performance (Schmidt and Hunter, 2004), personality for choice of transportation mode (Johansson, Heldt and Johansson, 2006) and for the effect of feedback targeted towards energy efficient behaviours in households (Shen and Cui, 2015).

2.2. The lens of building science

Research in the field of building science explores physical aspects of the built environment and includes subdisciplines related to building physics and fabrics, energy demand in buildings and the indoor environmental quality. Research on human thermal comfort and occupant behaviour within building science deals with bidirectional interactions of humans with their built environment. On the one hand, the focus of research on thermal comfort lies on the effect of indoor environmental conditions such as temperature or humidity levels on the (thermal) satisfaction of humans, how to optimize these conditions and the means to provide optimum conditions. The means range from devices directly controllable by the occupant, such as operable windows, to automation systems. On the other hand, research on occupant behaviour is related to the interactions between the occupants and aforementioned devices, and analyses potential triggers and contextual factors influencing occupant behaviour in buildings (Schweiker et al., 2018). The objective is a better understanding of occupants' interactions for purposes of building energy performance simulation including advanced behavioural profiles or the control of buildings adjusted for the occupants' interactions (Yan et al., 2015; Hong et al., 2016; Schweiker, 2017).

2.2.1. *What factors related to thermal comfort are considered in building science?*

One type of thermal comfort models are the Predicted Mean Vote (PMV) by Fanger (1970) or the Standard Effective Temperature (SET) by Gagge, Fobelets and Berglund (1986). These models consider the six main indoor environmental variables affecting human thermoregulation: air and radiant temperature, relative humidity, air velocity, clothing level and metabolic rate, i.e. the level of activity in a particular moment such as sitting in front of a TV or standing and cleaning. Based on experimental studies, in which these six factors were varied systematically and subjects had to rate their thermal sensation, the PMV model, which predicts the mean vote of a large group of people on the just mentioned sensation scale, was developed. This model includes aspects related to heat exchange mechanisms as well as human thermoregulatory processes, e.g. variations in skin blood flow or sweat rate, and is based on the assumption that thermal neutrality is equal to thermal comfort.

Another type of models, the family of adaptive comfort models (de Dear, Brager and Cooper, 1997; Humphreys and Nicol, 1998), considers the seasonal adaptation of people and resulting changes in their level of comfort. Based on people's adaptation to prevailing warm conditions during summertime, the temperature they perceive as neutral or comfortable increases compared to their perception in winter.

Recently, both approaches were combined in the Adaptive Thermal Heat Balance (ATHB) approach (Schweiker and Wagner, 2015), which permits the prediction of a mean sensation vote based on the above six factors and seasonal effects.

Other studies in the field of thermal comfort consider e.g. the influence of perceived control (Brager, Paliaga and de Dear, 2004; Boerstra et al., 2015; Hellwig, 2015; Schweiker and Wagner, 2016), personality traits (Schweiker, Hawighorst and Wagner, 2016), physiological differences such as gender and age (Karjalainen, 2012; Kingma and van Marken Lichtenbelt, 2015; Mozaffarieh et al., 2010) and cultural factors (Brager and de Dear, 2003; Shove et al., 2008; Chappells and Shove, 2005). Besides these variables being considered and their effect analysed, they are not (yet) implemented in models predicting thermal comfort, and there is still substantive unexplained variance in comfort experience between people (Schweiker and Wagner, 2017).

3. Research question and objectives

Based on the above background, our proposal has as its research question: Does knowing the interaction between psychological factors, individual preferences for thermal comfort and control preferences lead to greater participation of consumers in load-shifting behaviours through tailored solutions?

From this, two main objectives follow:

a. What individual preferences and differences exist in building occupants in relation to their comfort requirements, psychological characteristics and types of DSM options?
b. How can solutions be tailored to individuals to increase acceptance of and engagement with load-shifting actions while not affecting the perceived level of thermal comfort?

In this research, we bring together differential psychology by focusing on psychological inter-individual differences and building science by focusing on physiological differences between people, such as age and gender, and the effect of physical control options. We not only draw on concepts from both disciplines but also use methods from both.

4. Methods

In the following, we describe the methods used in the fields of differential psychology and building science, which form the basis for our approach in addressing this research design challenge.

4.1. Methods commonly used in psychology

Psychology uses both quantitative and qualitative approaches. The former rely on inferential and descriptive statistics to analyse, present and interpret data gathered by researchers largely through standardized or objective instruments. The latter rely on qualitative methods of data gathering such as interviews and diaries. Psychology is largely a theory-driven field, i.e. from a theory, hypotheses are generated and empirically tested, predominantly using quantitative data.

The three most common research designs are descriptive, correlational and experimental ones, with the latter often considered the gold standard. The experimental design aims at establishing causality. It tests what the impact of one variable (the independent variable [IV]), manipulated by the researcher, is on other variables (the dependent variable[s] [DV]). For example, in a direct load control (DLC) scenario, participants might either be told that they can override any changes to temperature settings at any time or can never do so (IV: override yes vs. no). The outcome might be the willingness to sign up to a DLC program (DV).

In addition to the traditional experiment by which subjects are randomly assigned to different expressions of the to-be-manipulated variable, there are less strict versions of experimental studies, such as natural experiments whereby naturally occurring conditions are contrasted but not randomly assigned.

Intelligence and personality traits cannot be manipulated experimentally, i.e. we cannot randomly assign a person to a high or low intelligence or a high expression of extraversion, but of course, they can be included in experimental studies as mediating variables. For example, to what extent is the acceptance of direct load control mediated by neuroticism score? Personality is usually measured with self-report inventories in which individuals rate themselves on specific items. For example, they indicate their agreement with an item such as 'I prefer being alone'. Intelligence is usually measured with an objective test, i.e. an intelligence test.

4.2. Methods commonly used in thermal comfort studies in the field of building science

Thermal comfort studies are nearly exclusively focusing on quantitative methods. The main approaches can be categorized into field (or in-situ) and laboratory studies.

Researchers conducting a field study collect data of the indoor and outdoor environmental conditions in a building (either through existing or newly installed sensory equipment) and distribute questionnaires to occupants present in that building. This approach is comparable to natural experiments in the field of psychology. Measured data preferably includes the six comfort variables described in section 2.2.1. The questionnaire focuses on basic items related to thermal perception (mainly thermal sensation, preference and acceptance) together with demographics, building characteristics and study-specific items.

Laboratory studies usually take place in climate chambers, which permit tight control of indoor thermal conditions. The experimental design depends on the research question and often consists of distinct thermal and/or contextual conditions. Thermal conditions may vary in the temperature level, e.g. 20°C vs. 30°C, the speed of temperature change, e.g. steady-state vs. an increase of 3 Kelvin per hour, or the spatial distribution of temperatures, e.g. heated ceiling vs. heated walls. The context may vary in the number of control opportunities or persons in the same room. Data include physical parameters, questionnaires, and often physiological parameters, e.g. skin temperature.

Traditionally, the focus is on the average person, but the interest in factors driving diversity is increasing (Shipworth et al., 2016).

4.3. Our approach to research in addressing the challenge

The general focus is on empirical methods to collect primary data, as usually done in psychology. Modelling approaches are quite common in building sciences; however, whilst we consider modelling useful at the final stage, e.g. to estimate possible demand reduction on a national level, we first need to have a solid empirical basis for it.

The unit of analysis is the individual occupant of a building and its interaction with space heating and cooling. However, it is likely that groups of individuals would emerge from the analysis that form a higher level of analysis (male vs. female, young vs. elderly, extraverts vs. introverts etc.). Whilst it is likely to assume that individual preferences play a role in all cultures, it is also plausible that different factors determine interindividual differences within cultures, which would mean that research would have to be done in various cultures and different solutions developed. In addition, focusing solely on the individual would be sufficient for the third of Europeans living in single person households (Eurostat, 2018a). For individuals living in two or more person households and the periods they are not alone at home/in a room, constraints to individual behaviours, e.g. due to negotiated behaviours, have to be considered.

In terms of developing a research project, from our disciplinary backgrounds and current positions, the following elements would be likely:

4.3.1. *Focus groups*

Focus groups are a qualitative way of data collection; they are basically a group interview designed to explore what a set of people think and feel about a topic. In this case, the topic would be how participants could imagine interacting with the energy system in the future. What might motivate them to shift when they use energy in time? Would they like to have automation in the process or accept it only under specific conditions? What are their key worries with regard to various DSM scenarios, e.g. to what extent do they worry about loss of thermal comfort or would accept it for reasons of energy efficiency and cost savings? What are their perceived constraints, e.g. how would other members of the household influence their decision? The interviewer will in particularly try to elicit reasons for the answers in a first attempt to understand drivers of various opinions. Standard surveys of personality and tests of intelligence will also be conducted, together with a verbal exercise where participants describe their personality.

4.3.2. *A conceptual framework*

Based on a literature review and results of the focus groups, we would develop a conceptual framework. This framework would link the psychological concepts, prior findings from building science and insights from the focus groups to arrive at testable hypotheses regarding the relationship between DSM and users (see Figure 1).

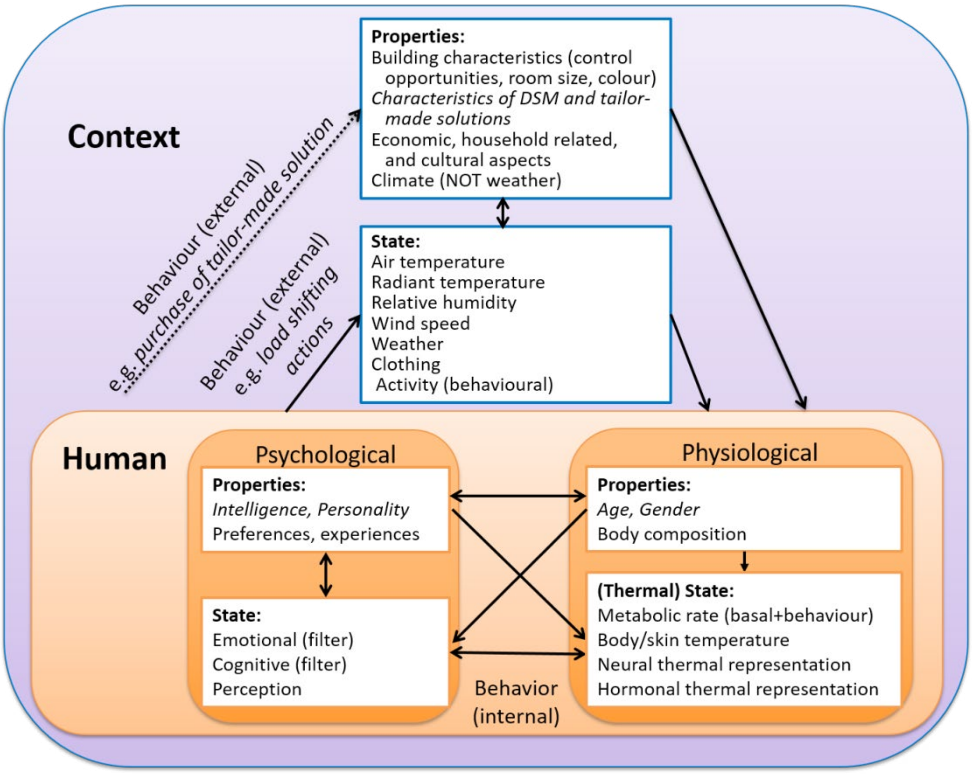

Figure 1 – Sketch of the conceptual framework to be developed.

4.3.3. *Item generation and testing*

Based on the conceptual framework and the results of the focus groups, a number of items will be generated in order to assess the constructs acceptance and engagement in relation to load-shifting actions by means of questionnaires. Pilot testing will be done with colleagues and students to ensure the items are clearly formulated; item selection will follow large-scale online surveys with calculation of reliability and internal consistency of items in line with principles of psychological test development.

Applying this newly developed questionnaire alongside with the existing questionnaires assessing thermal comfort and personality traits enables us in the later stage of the research project to triangulate the observations of participants' behaviours with their ratings on these constructs.

4.3.4. *Lab-based experimental studies*

We will conduct a series of experimental studies in our living labs in Germany and the UK, whereby participants will be exposed systematically to variations of partial aspects of tailor-made solutions derived from the conceptual framework to assess participants' interaction with future energy systems. We might present various incentives for participating in the future energy system that we expect to be differentially appealing to people with varying personality, intelligence, age, and gender characteristics. Similarly, we would present different DSM options in terms of underlying control strategies, e.g. direct load control with and without override option, and voluntary load reduction programs. Finally, the magnitude of temperature changes resulting from DSM options will be varied, and the impact on thermal comfort assessed. Ultimately, it will depend on participants' responses what solutions will be offered. This step will be done repeatedly to identify those incentives that maximally appeal to different people.

4.3.5. Developing and testing tailor-made solutions experimentally in the field

The tailor-made solutions will be developed in cooperation with industrial partners in order to increase their applicability and commercial viability.

The effectiveness of these solutions will then be tested through field studies. Two largely representative samples of individuals will be selected and matched based on their gender and age distribution as well as those variables previously identified to have a significant influence on the suitability of a solution. One of these groups will be provided with the tailor-made solution, the other group with a standard solution. The tailor-made solutions will vary across individuals and be designed depending on relevant household characteristics and preferences. Therefore, the questionnaire developed in the previous stages will be given to the individuals prior to the installation of the tailor-made solutions in order to identify the most appropriate solution based on the variables determined within this programme of research.

Both groups will keep their solutions for at least two years. This period is necessary because both standard and tailored solutions will likely cause initial behaviour change due to the novelty aspect. In addition, the length of measurement is required to capture seasonal differences in comfort requirements. We hypothesize that over the course of the trial, the tailor-made solution will have a significantly longer lasting and more positive effect on the acceptance and interaction with DSM and load-shifting actions and also on the perceived level of thermal comfort.

During the two-year period, individuals' thermal environmental conditions, energy use, satisfaction levels and interactions with the solution will be monitored alongside with outdoor weather conditions.

4.3.6. *Modelling the effect of tailor-made solutions on occupants' satisfaction*

In the final step, the results obtained through the field studies will be used to implement the gained knowledge with respect to the effect of tailor-made solutions on occupants' thermal satisfaction into thermal comfort models. Such models can be used in building performance simulations in order to quantify the effect of tailor-made solutions on future energy use. The results of these simulations can be incorporated into models of future energy systems, including the effect of tailor-made solutions on the scale and success of demand-side management programmes. These calculations will take into account the distribution of psychological traits, household characteristics and comfort preferences among the corresponding target area (e.g. city or country).

5. Discussion

5.1. The research output and its application

The output of our research would be a toolkit of tailored solutions to increase interaction of customers with the energy system, in particular demand-side management. Hence, greater benefits to the electricity system will result in addition to greater personal satisfaction and personal benefits such as greater monetary savings. Companies, e.g. energy suppliers, could offer those tailored solutions. For example, they could devise an online questionnaire to assess a person's personality traits, comfort preferences and living circumstances, and develop/supply the most suitable tailored DSM offering based on the responses.

5.2. Limitations

We propose mainly looking at two sources of interindividual variation: personality traits and intelligence. However, there might be many more factors that have an equal or larger impact on explaining variability in preferences between customers, such as value orientations. Also, given that the preliminary testing will be done in the lab, and only the final testing in the field, it might be that solutions that are preferred in lab settings are not the best ones in the field. Obviously, there is also the option that our initial assumption, that variability between consumers matters, is incorrect and that, in fact, tailored solutions are not superior to standard solutions as there might be very simple drivers applying to everyone, such as that the greatest monetary savings are the most important fact to increase interaction with the energy system. However, we would be able to identify this in the experimental field study that contrasts tailored and standard solutions; and whilst not conforming our hypotheses, it would bring valuable insights.

5.3. Conclusions

By looking at acceptance of and engagement with DSM through the lenses of both psychology and building science, a greater number and a greater variety of variables are considered, likely explaining a greater share of variability between people. That people will vary in their preferences is very likely based on evidence from both building science and psychology showing the huge variability between people. A mono-discipline approach would likely miss out on important variables. The same is true for methods – by explicitly encompassing core methods of psychology, such as experimental design, and of building science, such as careful sensing of the environment, a richer data set is collected and can inform the outcomes.

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The Newton Machine: Reconstrained design for energy infrastructure

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1. Introduction

Energy, in all its forms, is essential to everyday and future living. Our inseparability from energy is not just a matter of electricity consumption and use, but includes our inseparability from all infrastructures of generation, transmission and storage. Our lives are energy-rich, but our relationship with energy is threadbare; electricity is ethereal and distant, a number on a meter. This paper describes a community-led project that has already begun to change that relationship. It is the design and prototype of an energy generation and storage solution – a gravity battery we call 'The Newton Machine' – built from what is to hand, what is in the local landscape, with local expertise.

In this paper we document our community-led experiments to build and test a Newton Machine at the edge of Europe, in the northern islands of Orkney, Scotland. As a visualization and proof of concept, the gravity battery will power an electronic keyboard. Our aim is to demonstrate how smarter energy storage infrastructure can be prototyped in communities at the periphery, and then developed into a design method to be exhibited, shared and used elsewhere.

Our research question asks: What happens when domestic products do not end at the electrical cable and plug? How can we rethink the design process to incorporate what happens 'beyond the wall' to include the whole energy infrastructure and ecosystem? This approach aims to focus on the local and bespoke rather than global and generic.

The paper explores our refiguration of energy infrastructure as technical, social, environmental and political, within a local community and island landscape, drawing on design, literary studies, social studies of infrastructure and energy anthropology. Our interdisciplinary methodology draws on a longitudinal ethnographic study on energy futures in the local island community which informs the speculative design and prototype demonstration of an energy storage machine built from local 'scrap' materials in collaboration with a small island community. The research question could therefore be refined to one that asks how our everyday understanding of energy infrastructures can be reimagined and remade through collaboration with interdisciplinary social science research and practice.

2. How to design for energy infrastructure

Infrastructure has long been understood not just as physical architecture, but as social and technical. Infrastructure must be designed and maintained. It is the social and material residue of its negotiations and politics. Perhaps the most famous example is Langdon Winner's case study of a Long Island bridge, which was built too low to allow buses carrying low-income and racial minority families to pass; racial politics was built in (Winner, 1988). Ethnographer of infrastructure Susan Leigh Star has proposed nine properties that define infrastructure as a socio-technical system that has to be imagined, designed, manufactured, installed and maintained over decades, or sometimes (in the case of water infrastructures such as aquifers; Edwards, 2004) even over centuries (Star, 1999). Three key dimensions out of these nine that are important to our work are:

- *embeddedness*: infrastructures are embedded into existing social and cultural relations, and cannot just be replaced without major re-arrangements, e.g. they often include large-scale public architectures such as power plants and electricity pylons;
- *reach or scope*: they extend and reach over extensive spaces and over long periods of time;
- *visible on breakdown*: they are often taken for granted, but become visible on breakdown – when the lights go out it is then that we ask about where our power comes from and wonder what has broken down along the way.

Infrastructure is also embedded in the landscape and entangled in environmental concerns. A classic example of this is the Panama Canal as a transport and water infrastructure. Ashley Carse (2012) notes that the management of the canal includes the surrounding forest watershed, since without that water resource, the canal cannot function. The canal as an infrastructure does not stop with its walls, but includes the so-called 'natural' environment of the forest and, indeed, the people who live in the forest who are also involved in the water supply for the canal. Following these examples, we consider infrastructures as extended not only over time and space, but also including places and people.

Rather than energy storage as a problem only for infrastructure operators and national governments, we consider it as a social, technical and environmental infrastructure. For our design work, we consider how people and their local places might be participants in energy storage. This approach enables us to make energy infrastructure, and its futures, open to public and local community participation. By including people in energy storage infrastructure we go 'beyond the wall', pointing to how people (not just 'users') can understand electricity as energy infrastructure, from renewable energy generation (micro wind turbines) through to transmission (smart grids) and local storage (electric car batteries).

An example of this approach to refiguring energy infrastructure in community practice is the Zimbabwe Bush Pump (de Laet and Mol, 2000). The assembly of this clean water pump contains instructions for the whole community, who are all needed and involved in the installation (including the local water diviner who should be involved in identifying the location). The pump is designed to be robust but de Laet and Mol (2000, p. 225) argue it is a "*fluid technology*" since it is well-defined but its components can be altered, so that if one component breaks it can be replaced with something to hand in the local community (a piece of recycled leather, or a bit of rubber tyre). Our project is similarly committed to designing an energy infrastructure that addresses the problem of local energy storage, but does so using local materials, local environment, local people and their skills, so that it can be both constructed and maintained by those involved. In short, through participation in its installation and maintenance, people have their understanding of energy infrastructure refigured: it is never invisible, or 'behind a wall'.

Our approach follows the consideration of 'scrap' as a valuable resource rather than as waste. It draws on the work of anthropologist of technology Lucy Suchman (2002, p. 91), who has refigured design innovation as the "*artful integration*" and re-arrangement of existing social and technical systems, rather than the creation of shiny, decontextualized devices. She has argued that technology design does not end with a product, but is a continuous process, as its relations between parts and people shift through ongoing and diverse use. Following Suchman, we consider our Newton Machine as the artful integration of local materials and spare parts – innovative design of energy infrastructure as the reuse of what is to hand and available to the community.

Designing infrastructure devices so they can be made and maintained with locally available, low-cost and easy to find components is also resonant with many citizen science projects (Kimura and Kinchy, 2016). These projects, which often support local communities who want to conduct their own environmental monitoring, require equipment that must be accessible to a diverse range of people and places. The design politics is locally led, rather than global-manufacturing led, because such open design solutions are what works best for the artful integration of local social, technical and environmental parts and their problems. Science studies scholar Steven J. Jackson (2014, p. 221) calls this approach "*broken world thinking*" which he describes as taking "*erosion, breakdown and decay, rather than novelty, growth and progress*" as the approach to technology innovation. As Jackson points out, it is only through careful repair that any infrastructure can persist. Similarly, in our approach to designing the Newton Machine, we start from the understanding that spare parts and eroded old machinery, found in the local community, are the starting point for our innovative design. The Newton Machine, as energy infrastructure, embodies 'broken world thinking'.

Together these insights provide the background for what we call our 'reconstrained design' approach to energy infrastructure.

3. What is a Newton Machine?

From the outset, we sought to frame the Newton Machine not simply as a thing made from material components, but as a process that requires and builds relationships between people and things. To make a good Newton Machine, in other words, means making good relationships between people and things.

The purpose of a Newton Machine is to reconfigure local resources (people, places and things) to store electrical energy over time.

The open-source, 'reconstrained design' approach of the Newton Machine necessitates a clear and adaptable set of principles: a **manifesto**. Therefore, we declare that a Newton Machine is designed according to the following specifications:

- **Renewal of existing resources**
  Resources are always limited. This becomes especially visible on the periphery and at the edge. We design for the reuse and renewal of existing materials, such as scrap and waste, that can be found to hand.

- **Innovation redefined as 'artful integration'**
  Design innovation is redefined as the making of new things through the "*artful integration*" (Suchman, 2002, p. 91) of old or existing resources and ideas.

- **Design solutions that are local not universal**
  Rather than designing objects to be replicated the same everywhere, and then tweaked, we design things that solve problems premised on the local environmental resources, local materials and local production skills.

- **Designed things are made of people and places**
  Things are not just made of materials and technology. This design recognizes and requires well-working social relationships to make the design possible (e.g. between engineers and craftspeople), and environmental relationships needed to make the design operate (e.g. cliffs used for creating potential energy).

- **Energy as a visible companion**
  Electricity can seem invisible, out of sight behind a socket, and therefore inexhaustible. We create energy 'things' that lead people 'through the wall' – to form not just a visible relationship but a familiar companionship with energy, both in terms of sustainable consumption and generation.

- **Energy infrastructure as domestic**
  Energy infrastructures are vast, multinational-scale systems that are beyond the control of the domestic home, or of comprehension by most of us. We make an energy infrastructure that is domestic and personal in scale.

- **Self-determined energy machine**
  Electricity grid infrastructure is often entangled in complex energy policy decisions that leave little room for self-determination. Our energy machine design supports small-scale electricity generation and storage for the self-determined.

- **Freedom from electricity grid constraints**
  We design for living outside and at the edge of the electricity grid network. Through energy storage, our design increases autonomy and freedom from energy markets, limited capacity and other grid constraints.

- **Community-making machine**
  We design for bringing people together and making communities through the fabrication process. A working Newton Machine should successfully contribute to community making as well as storing energy.

- **Energy storytelling machine**
  A Newton Machine can exist as a story, on a scrap of paper, in a plan for designing to this specification. Whether oral or written, imaginary or material, a Newton Machine can still work to draw people, places and things together and reconfigure their energy.

4. On site: Building the Eday Newton Machine

The stated objective was to build and demonstrate a working prototype of a gravity battery on the island of Eday in Orkney, Scotland, using only local resources, in four days. Our team of five researchers arrived on a Sunday evening in late October, after a 24-hour weather delay, with no tools or materials of any kind. By Thursday afternoon we were running a public demonstration of a gravity-powered electronic keyboard for a large group of islanders including the pupils of the local school. Here is a brief account of the process.

4.1. Background: Why Eday?

The Orkney Islands, off the northeast coast of Scotland, have been a test bed for electricity technology for over sixty years: the UK began wind turbine tests there in the 1950s. More recently, the islands have had Smart Grid technology installed on their local grid (in the form of Active Network Management) and lithium grid batteries. The islands are developing their own hydrogen fuel network to bypass the grid; they have already invested in their own energy future, by individuals installing over seven hundred micro wind turbines. These islands are therefore an important site for testing energy futures, with a highly aware and energy technology-literate community.

Eday is a particularly energy proactive island community. The islanders have pursued collaborations with the industry and academics to improve their self-determined energy generation and storage solutions. These projects, including EU Horizon 2020 *SMart IsLand Energy systems* (SMILE)[1] and the Orkney *Surf 'n' Turf* hydrogen energy storage project[2], have been conducted in collaboration with Community Energy Scotland, which acts as the coordinating partner. These long-term collaborative and experienced partners in citizen-led renewable energy projects, Eday Renewable Energy Ltd. and Community Energy Scotland, were our citizen partners in this project.

Although Eday is a remote rural island with a population of less than 200 people, they are well acquainted with the importance of energy – and its relevance to their lives and the island's economy. Fuel poverty is widespread – due to energy cost, housing standards, incomes and climate. Recognizing their fragility, Eday's residents have taken active steps themselves to improve their energy outlook. The community built and operates a 900 kW wind turbine to benefit from the abundant wind resource.

Unfortunately, the wind turbine performs below its potential due to the weakness of the Orkney electrical grid. In some months, the zero-carbon electricity blocked by grid curtailment is double the number of megawatt hours the turbine is allowed to generate. Grid limitations cause the single turbine to lose typically 1.8 GWh of production a year. Eday is a very practical community. 'Make do and mend', a historically necessary behaviour evoked in remote communities, lives on in its culture. To tackle energy storage at the domestic scale using everyday technology is therefore a challenge that is highly relevant.

4.2. Island resources: Community, materials, location

None of us had ever been to Eday. The Newton Machine is about community cooperation and resilience, which meant that opening a dialogue with the wider community beyond our contacts at Eday Renewable Energy was an immediate priority. A meeting was held at the island community centre on the first day, where we presented the idea of our four-day challenge and invited the whole community to join us, whether as

1 http://www.h2020smile.eu/ [Accessed 14 March 2018].

2 http://www.surfnturf.org.uk/ [Accessed 14 March 2018].

participants or spectators. The response was overwhelmingly positive: several people volunteered to help us build the machine, tools and other materials were offered and near the end of the meeting someone suggested a possible source for a scrap motorcycle.

The next step was to gather materials from around the island. Our first stop was an abandoned church which held a variety of items including an old Kawasaki motorcycle. Unfortunately the engine was seized, making it unsuitable for our purposes. The second stop, the new church, held a large brass ship's bell which we considered using as the gravity battery's falling mass. (We eventually decided to use a large water container which allowed for weight adjustment.) The third stop was a vehicle scrapyard, where we found usable gears and other spare parts. By the end of the first day we secured the donation of a usable scrap motorcycle and spare parts, an electronic keyboard for the demonstration, along with angle grinders, socket sets and other essential tools.

Over the next three days a range of material challenges arose which we solved with the help of the community. For example, one of the volunteers melted aluminium cans with a blowtorch to make improvised bushings, and we used an old lathe at someone's house to machine specific replacement gears to fit with the motorcycle engine and gearbox that formed the central mechanism of the gravity battery.

The third challenge was to locate a suitable site for the demonstration. The gravity battery required a drop height of at least several metres. Our first choice was the disused quarry which had a sheer drop of ten metres and a dramatic seafront location. Another possible location was the cliffs near the ferry dock. At the last minute, however, we decided to stage the demonstration outside the pier shed where most of the building took place. It was reasoned that this location would save transportation and setup time. Located at a central crossroads on the island, the shed would ensure a larger audience, including school children, while minimizing safety concerns and other logistical issues. To achieve the necessary height for suspending the weight from a raised pulley, we used a tractor owned and operated by one of the volunteers.

4.3. Demonstration: From theory to action

The Eday Newton Machine is essentially a gravity battery comprising a falling mass (in this case a water bottle) which turns a generator via a motorcycle gearbox thus generating energy in real time. For demonstration purposes we used the electricity to play music via a keyboard. The mass is lifted with energy generated by a solar panel and can be stored for release when it is needed. This creates an incredibly tangible relationship between energy generation and consumption: for example, the mass fell more quickly if the volume of the keyboard was increased.

The demo was scheduled for after lunch on the fourth day. By late morning a crowd had gathered. The motorcycle chassis that formed the heart of the machine was strapped to a wooden pallet. School children, wearing reflective vests for safety, lined up in front of the crowd and showed drawings of the gravity batteries they had designed earlier in the week. Everyone stood facing us in a semicircle and waited for the show to begin. The mass was now suspended several metres above the ground, the energy being stored until needed. We called for attention, released the mass, wires were connected and the keyboard came to life. The performance lasted several minutes, then the keyboard fell silent at the instant the water container touched the ground.

That evening there was a meeting at the community centre. At times it was emotional, as people discussed past achievements like the installation of the community-owned wind turbine, along with possible futures of the island itself. We tried to impress the point that, given enough time and ideal conditions, their energy storage solution would not be a gravity battery – which was something we had created out of the particular materials and terrain of our home island, Madeira – but rather a bespoke solution for Eday, taking advantage of local conditions, like a flow battery made with seawater. But we had four days to produce something spectacular with the community, so we decided to make an Eday version of a gravity battery – and on those terms, we succeeded.

5. Discussion: Instruction Manual for the Newton Machine

The Eday Newton Machine is only one instance of the design. Our design is not intended to be specified by manufactured components, but is defined only by its principles in the manifesto. Newton Machines are fluid over space and time, as they are assembled by different people in different places, with different tools and expertise. Indeed, we do not even define the Newton Machine as a gravity battery; using potential energy in the landscape as the mechanism for energy storage is just one solution. Other Newton Machines might use other energy capture mechanisms available in their locations.

Given this openness, how can we make the Newton Machine travel as a reconstrained design solution to other communities and places? What might an instruction manual look like for the Newton Machine, when we do not define components or assembly but only the principles?

We have established an open, online design manual in the form of a wiki[3], available for other communities to add to. Following our understanding of the design problem for energy infrastructure, it outlines the social, technical and environmental parts involved in any particular Newton Machine. For the Eday Newton Machine, the wiki provides a detailed record of the building process, but it also describes the web of social relationships – it was built out of curiosity and the exchange of knowledge, cooperation and mutual support. The manual therefore also includes personal attitudes towards energy, local and distinct energy practices, and serves as a testament to the accumulated wisdom that a community can offer.

Within this online design manual, we include the Newton Machine design manifesto, which we have reproduced in this paper. Simply put, if an energy storage device follows these design principles then it is a Newton Machine.

Finally, the reconstrained design principles for the Newton Machine travel through an exhibition of a series of Madeira-built Newton Machines, on show at Centre de Cultura Contemporània de Barcelona (CCCB). This exhibition is not the representation of some final output, but is integral to our design process. The operational Newton Machines in the gallery work to engage individuals and communities who experience their aesthetics. Documentary images, as well as ethnographic, poetic and literary descriptions of the Eday Newton Machine, provide further refiguring of this energy storage infrastructure for visitors and readers.

Through this open design process we invite the 'artful integration' of many local resources, in many communities and environments: Newton Machines that might be very different in practice to our Eday Newton Machine, yet remain true to the principles. Through the design principles we have outlined for a social, technical and environmentally reconfigured energy infrastructure, we hope that the often distant issue of the electricity grid, beyond the wall, is transformed into self-determined and self-made energy infrastructure; a visible and valuable part of everyday climate and energy-aware living. In short, when energy infrastructure goes through the wall, people can reach through to take ownership of the energized world beyond.

6. Acknowledgements

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CONCLUDING DISCUSSION

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The conclusion is divided in two parts: Part one will discuss SSH research questions derived from the material presented by authors in the respective sections; part two will elaborate on the concept and interdisciplinary potential of structuring this collection around three distinct reference problems.

Control

The first section of this collection (Challenge A) relates to issues of 'control'. The first paper picking up this issue by *Smedberg* and *Light* interprets this as multi-level governance problems, territorial and policy control, and ultimately sovereignty/autonomy in community energy processes. Arguably, the aspect of social control is of crucial importance in energy transitions, referring to a basic question of social science research: Who/what determines the social process and how can interventions be designed that will achieve a predefined goal? The whole idea of political systems in Western democracies relies on the idea that society is 'controllable', or at least can be steered in a certain direction (Willke, 2007). The basis of steering potentials for political interventions in society are formal rights of exerting power and control over a certain policy field like energy. Still, the research design by Smedberg/Light shows that even in the absence of full formal powers, Orcadians have been creative in building informal but effective empirical ways of realizing certain energy goals, reflected by many innovative local energy projects and pioneering in the field of RES. Consequently, for the purposes of overarching research designs, we can conclude that the distinction and balance of *formal vs. informal (social) control* is worth being targeted by energy-SSH research. Both design and STS studies have triggered potential vectors of relevance, denoting the factual way Orcadians deal with the material and social reality at hand (design), as well as socio-material repercussions in general (STS).

Wokuri and *Pechancová* refer to a similar vein of research in that they target local governing modes as reflections of control. How is it possible to reliably predict the successful planning and implementation of community energy projects under involvement of public, private and non-for-profit stakeholders? The issue of locally controlling the output of energy initiatives to achieve higher RES shares based on sustained funding and collaboration is what their focus leads us to. Reference to their final conclusions of establishing "*broad coalition[s] of actors*" and "*enabling [...] citizen or community groups [...] to raise funding by themselves*" (p. 42) evokes research avenues between management, politics and law: What concrete action strategies should local actors take in order to execute the often abstract energy transition goals formulated at value levels (e.g. profitability, sustainability, efficiency, security of supply, etc.)? Which multi-level governing influences are key to this process, pertaining to sources of conflicting/enabling policy, as well as legal considerations of concrete organizational designs of energy initiatives and their financing sources? Finally, most valuable is their insight into the degree of complexity (organizational and technical) which obviously factors in the development of local energy transitions, as it separates rather simple (biomass, biogas and photovoltaic) from rather complex (onshore and offshore wind power) energy technologies (p. 41). The degree to which municipalities are able to attract and manage implementation of the latter, according to the authors, is a basis for further hypothesizing and research.

Complexity is also a keyword in the research design presented by *Turhan, Şorman,* and *Larsen*. The central thesis is: Control over narratives of energy system development conditions the transition of the very system. Therefore, the question of what technical and social solutions to energy problems are presented and favoured/discarded very much depends on dominant discourses in this field. Those open up or close down as well as narrow or widen pathways for possible transitions. Consequently, institutionalization processes which render certain developments more likely than others, in the authors' view, should be investigated by SSH research through a combination of qualitative and quantitative methods. The special focus is the issue of intervention into complex systems and the ensuing decision-making processes under considerable epistemological, political and economic uncertainty. Now, as engineering science expertise is still dominant in this field and cannot be fully substituted, SSH research is called for in its ability to provide orientation concerning distribution of risks and dangers, opportunities and costs. In this regard, besides idiosyncratic perspectives, energy justice as societal issue is at the centre of what the authors call to be addressed in this way. Overall, they want to investigate and propose an understanding of how energy narratives form and shape transition processes, by inclusion of STS, future studies and scenario planning. This approach can be seen as a means to achieve social control over the unintended side effects of energy transitions.

Stability and Change

Section B assembles a variety of authors and their disciplines around the reference problem of 'stability and change'. This distinction becomes apparent in the contribution by *Buchmann, Heffer* and *Parag*. Examining energy start-ups and ecovillages, the authors focus on actors challenging the status quo and therefore accentuate change. In particular, ecovillages are stressed in their role as 'niche-innovators', domesticizing a protected space that allows for radical experiments decoupled from the mainstream of society. In this way, the authors conclude that "*these tiny settlements had a disproportionate effect in bringing about a regime transition towards energy sustainability*" (p. 52). Looking at future research opportunities regarding ecovillages, they suggest an "*in-depth exploration of the energy footprint of ecovillages' tourism industry*" (Ibid.). This potential 'green paradox' is complemented by another ambiguous phenomenon that pertains to energy start-ups: "*Environmentalism may be a great force in recruiting employees for the ES [energy start-up], but was not deemed as relevant for selling the product*" (Ibid.). This contradiction is a fact start-ups have to cope with, and is worth further research illumination through policy, management and organizational sociology perspectives. It relates to the balance of stability and change as it demonstrates that start-ups cannot change everything at once and are subject to established market rules themselves.

Lis, Wagner, Ruzzenenti and *Walnum* analyse processes of change by unravelling unintended side effects around electric mobility and its broad-scale societal introduction. Their approach of considering the wider societal implications of this socio-technical innovation resembles technology assessment, and provides readers with an account of what the conditions and premises – explicit and implicit – of introducing electric cars might be, apart from what proponents of the technology promise. By bringing together economics, sociology, social anthropology and engineering, they deliver a helpful account on (initially) assessing a technology from various viewpoints, yet merging the disciplinary questions (e.g. technical and social considerations) around the overarching aspect of unintended side effects, and the reference problem of stability and change. Their proposed research design of how to go about and examine both what we could already know about electric mobility consequences and what is left for digging deeper incorporates four dimensions (*cognition, action, prediction, creation*) in a socio-technical systems design, well prepared for further unfolding. *Schippl* and *von Wirth* focus on the same overall topic (electric mobility), yet apply a less holistic view on mobility transitions. They concentrate on a particular element of mobility, i.e. the spatial dimension, and their provision of first evidence and indications of why and how the spatial context has been underestimated in electromobility research is thought-provoking. While urban and rural contexts often play a highlighted role in explaining societal conditions (e.g. for socialization, political attitudes, access to services etc.), this category, according to the authors, has received little attention in analysing mobility transitions. As a consequence, the question of how mobility based on combustion engines is replaced or complemented by battery electric vehicles is largely influenced by spatial characteristics, and so are *patterns of stability and change*. Based on their geographical and technology assessment expertise, the authors are able to demonstrate this tendency for the Swiss energy transition as well, where decentralized energy systems and RES diffused in line with spatial contexts and local conditions, so the authors' hypothesis.

Märker and *Milchram* emphasize the institutional dimension in explaining processes of stability and change. More precisely, they comprehend values as an underlying force that shapes institutions. In their understanding, "*values are relatively stable underlying normative guiding principles for changes in a society*" (p. 78). Bringing stability and change together through their intersection with values connects directly with what we have described in the Challenge B introduction above: Stable structures and institutions are necessary features of social life, providing orientation and enabling action. Yet the authors go a step further in that they "*propose a framework for institutional analysis that identifies the roles of values in institutional change*" (Ibid.), based on the Institutional Analysis and Development (IAD) framework. For their understanding of values, they draw on institutional economics, moral philosophy and sociology, thus combining a powerful array of disciplines to reach an overarching incorporation of values into their framework. The influence of (highly abstract) values such as sustainability or justice on concrete action situations in different empirical energy contexts is a highly relevant field of SSH research, which is forcefully demonstrated by the authors. *Greene* and *Schiffer* are interested in a comparable vein of research, in that they ask for the conditions of change through the lived experience of different geographical contexts, on various potential scales. Overall, "*the findings of this investigation indicate that understanding dynamics of stability and change at a local scale is crucial for informing* *decision making and development interventions*" (p. 63). Their ethnographic approach on everyday energy practices and how these are shaped by socio-technical developments on a meso and macro-scale over time is another component in researching the stability/change nexus. The lens of micro-scale empirical studies analysing the lived experience of energy systems complements some of the rather generalized perspectives in the field of transitions and innovations. This concrete social interaction situation in households and/or communities is most important, for it is the only social entity we actually experience directly, because levels like organizations, regimes, landscape, or society are all mediated through interaction situations and can never be experienced directly, as such. In this light, energy-SSH research is well-advised to follow up on the design presented by the authors and conduct this style of research with the aim of further learnings across cases and countries as well as considering policy implications.

Oliveira and *Baborska-Narozny* complete Challenge B contributions on stability and change. In their paper, the important triangle between design, construction and use of (energy-intense) buildings is referred to. Their approach and the research questions asked are a strong indicator for the fact that SSH research plays an uplifted role in fields traditionally dominated by rather techno-economic perspectives: While one might assume that technical solutions and architectural features determine the energy catalysis rate of buildings primarily, the authors demonstrate how communication patterns between designers, constructors and users shape energy consumption and savings potential. This applies to feedback between those three actor groups both for initial construction, and for building operation to ensure that all social potentials have been lifted and 'broken feedback loops' are avoided. Finally, the authors are able to highlight *presentation of feedback data* and *ownership of engagement* (p. 91), based on their workshop results, as central variables for improving feedback communication. Additionally, the application of theoretically inspired SSH concepts in the field of built environment is one remedy they suggest to tackle improved consideration of energy issues, a key deduction for energy-SSH research.

Capacity-Building

Proponents of modern digitized energy infrastructures make the important assumption that the public will adapt to the new technological *Lebenswelt*[1] once the opportunities become clear – calling on the *homo oeconomicus* and the *rational woman* in each of us. Yet this premise is rather precarious, for their case rests on nothing less than the broad-scale modification of public attitudes towards (compare Büscher and Sumpf, 2015):

- New technical devices which are 'intelligent, self-healing, autonomous machines' (Amin, 2001; Ma et al., 2009; Ramchurn et al., 2012), and whose operation is opaque to large parts of the public;
- Complex and opaque new markets in which it is unclear "*who reaps the benefits, who bears the risks and burdens*" (Kasperson and Ram, 2013, p. 94);
- Public administration and governmental institutions, which oversee the development of energy infrastructures, and on which the public has to rely (Cavoukian, Polonetsky and Wolf, 2010; Pearson, 2011; Hoenkamp and Huitema, 2012).

Up to now, the public has never been asked to be actively involved – voluntarily – in order to realize the ideal of a rational, effective 'smart' electricity system. In future, people must face complicated technology, opaque markets, and abstract regimes more actively, and therefore, they have to cope with situations that demand decision making and reflexivity capacities of them like never before in energy matters (Büscher and Sumpf, 2015). The authors in this dimension of the research design challenge present creative ways to allow for the active involvement of those affected by the energy transition, thus contributing to *capacity-building* in energy systems.

Peer-to-peer (P2P) markets, locally or trans-locally, present an opportunity to participate in advanced energy markets between micro-energy operations and consumers. *Fell* and *Neves* raise the question if there

1 *Lebenswelt*: literally, the world of lived experience.

is a difference in commitment between locally situated networks or wider area interactions. Is proximity a factor participants weigh in if engaging in P2P markets, and why should it be? Is it about knowing people, or doing good for a community people are included in? This important question relates to the works of Mary Douglas and Aaron Wildavsky (1983), who presented the concept of competing lifestyles influencing choices, based on a cultural risk theory. Egalitarian lifestyles, for instance, would tend toward locally centred interactions among equals for the benefit of the group. An individualistic lifestyle, however, would foster seeking to fulfil individual goals, wherever the opportunity might arise; personal interaction is not mandatory in this lifestyle model. In this sense, comparing currently running projects like those that the authors suggest is a promising strategy to fine tune future efforts in this regard, and explicate ways of mobilizing individual and corporate actors to participate in P2P markets.

Participatory Energy Budgeting (PEB) is another creative approach to include users into efficiency measurements in units of neighbourhoods or equally identifiable social groups to achieve control over a budget of usable energy. Having a choice in setting goals and selecting activities encourages active behavioural change; deriving satisfaction and enjoyment via self-accomplishments and evaluation of self-performance enhances 'intrinsic' motivation - that is the thesis of *Della Valle* and *Poderi*. However, this attempt to foster active involvement utilizes social mechanisms as well, in that the participants of PEB have to bridge uncertainty about the performance of all the others involved. Communication of performance of others is mandatory, which leads to reciprocal observation (using real-time feedback enabling digital technologies). In the sense of Jon Elster, social norms become the influential factor in conditioning actions (Elster, 1994, p. 24), as complying or not complying to the groups' goals and activities possibly leads to emotions of embarrassment or shame. In any case, the overall goal is given, i.e. efficiency of energy use, yet under inclusion of choices within the framework presented by the authors. Following up on this mixed individual-contextual approach with concrete PEB implementation steps could be rewarding for energy-SSH research. In particular, it would be interesting to evaluate to what degree the participatory element (starting off with an 'awareness event' and 'public consultation meetings') affects capacity-building, because it initially increases complexity for participants instead of reducing it, which is often seen as prerequisite for broad-scale engagement.

From an SSH perspective, heating and cooling buildings initially represents a rather indifferent technical operation: What is needed is a heat source, a distribution network, thermostats, and then, room temperature is raised or lowered to an average thermal comfort level. *Schweiker* and *Huebner* ask if there is feasibility and effectiveness in a more differentiated and tailor-made heating regime pertaining to building occupants. To achieve most of the efficiency improvements, the two researchers claim, it is necessary to gain insight on two levels: The building in question and individual occupants. Accordingly, they see psychology and architecture as the main knowledge sources for their research, which is timely and needed with respect to the high energy waste in buildings across Europe. They treat the occupant-building interaction as research entity and focus on increasing occupant's active participation in load shifting through a framework of tailor-made solutions, considering social (individual occupants) and material (building) characteristics. Through the combination of psychology and building science, the authors arrive at an important intersection of SSH-inspired energy research aimed at improving building energy use. As an extension, one could ask about possible inclusion of sociological expertise into this highly relevant research, so that further 'contextual factors' (see former contribution on PEB) are reflected upon to complement individualistic preferences, thus reckoning with the fact that individual decisions might have their origin in group dynamics.

In part socio-technical concept, in part activist demonstrator, *Watts*, *Auger* and *Hanna* narrate the construction of a 'prototype design' of possible elements for future energy infrastructures. In doing so, they attempt to raise the motivation to act, become involved, using local knowledge and skills as well as resources and conditions (geological, geographic, demographic, etc.). In trial and error activities, they attempt to generate knowledge about the possibility to generalize the motivational aspect of local involvement, and broaden the perspective of all participants toward a more holistic view on energy. The question now is: How might the demonstrator activities be further developed, sustained and scaled up? In this regard, standardization attempts of Newton Machine designs could be useful, because this would make the process and concomitant activities more transparent and subject to academic observation and duplication. Even though the authors emphasize the localized, individual character of each of their designs so far, reception and progress in the energy-SSH community would possibly benefit from a more systematically controlled approach. This is particularly true when thinking about applying this method to diverse contexts with the aim of capacity-building and a reliable output, which is more likely to be achieved with increased standardization, without giving up the idea of locally idiosyncratic experiments. The most interesting aspect of the Newton Machine design, in representation of all the proposals discussed here, is the creativity and diversity on how to increase the action capacities of citizens to cope with a formerly 'invisible' infrastructure. Evidently, social innovations are needed to stay on course with energy transitions across Europe.

Final remarks and outlook

The applied concept of using reference problems (control, change, capacity-building) to provoke interdisciplinary research designs has proven useful throughout this design challenge collection. First of all, it is apparent that all three sections have attracted sufficient paper contributions, so that the general separation into these three research areas at a rather abstract level of generalization seems to create resonance in the community. *Stability and change* are the variables with the most widespread appeal, reflected by six papers in the RDC. The underlying field of transitions and innovations research has provided a large basis of literature that many authors relate to, taking ideas further or providing new takes on the phenomenon. *Capacity-building* is the second most attractive reference problem (four papers), providing participating authors with a basis to present innovative research designs pertaining to the mobilization of public and corporate actors to participate in current and future energy markets. Arguably, the *control* dimension is the smallest section, due to a heavy penetration of technical (e.g. control of supply-demand equilibrium) and economic (e.g. control of critical market transactions) approaches in this domain. Yet the perspective of social control that authors have added here as an enrichment to the debate has potential to supplement engineering and economic approaches, and also create new opportunities for socio-technical collaboration in this field: While some contributions can help developing new approaches (e.g multi-level governance, political autonomy, intervention in complex systems), the RDC can contribute to trigger new research in this area, bringing researchers of different (social and technical) disciplinary backgrounds together around researching control.

The latter is at the heart of the RDC: The concept has worked because many researcher teams with different disciplinary backgrounds have engaged in common, unified approaches without separating their parts distinctly along the involved disciplines. This is visible in both socio-technical author teams, and in SSH-based arrangements throughout the sections. In a majority of cases, researchers have managed to develop their designs in focusing on the reference problem of their respective section, and not around their personal academic background. In applying their (disciplinary) theories and methods to the problems of control, change or capacity-building, author teams to a large extent have succeeded in generating designs that are more than the sum of its parts, because they work independent of the disciplinary backgrounds of participating authors. The reference problems created a way around disciplinary gaps, and provided integration potential through channeling researchers' attention toward the problem at hand, and not merely their disciplinary academic definitions and comprehensions. As this RDC embodies a first practical test of this kind of interdisciplinary design with little advance preparation for authors, not everything went smoothly and not every author contribution and editorial interpretation matches exactly with challenge descriptions. Yet, overall, we conclude a successful first application of this approach which hopefully finds imitators and contributes to author team follow-ups and the respective topics to prolong the initial potential described above.

The topics and research insights themselves are so diverse and vibrant that we cannot do justice to them in a fully summarizing way here (see above sections for details). Yet we would like to emphasize a few cross-cutting issues and internal references. An issue that comes up in all three sections is *design*. Design of technology, buildings, interfaces, social arrangements, processes etc. is a crucial element influencing social action, and conditions what interactions are possible in the first place and how human-machine interactions unfold. The socio-material connections in this regard are a key SSH research field that many authors in this collection have provided valuable evidence for. A second cross-cutting issue is a distinction, namely *individual/collective*. Several RDC contributions are interested in the decisive levels of analysis when it comes to environmental decision making, transitions and innovations, or local control and governance. This traditional SSH research area receives some thought-provoking revision offers throughout Sections A-C. A third overarching aspect would be *local context*. A majority of papers address issues of locality, either as direct reference to community initiatives, lived experience and broader geographical scale, or through case studies, spatial context and local experiments. Research on the community and/or national level – typically through comparison of research units or governance levels – has been an energy-SSH research priority for some time, so that author contributions in this collection underscore this development further. Our extended conclusion for policy making and future research agendas would be to consider the specific *interdisciplinary* deductions that authors have made in this regard, which have been presented in the prior conclusion sections. Finally, we urge RDC authors to get in touch with other authors from this collection for the purpose of collaboration, since there are intersections along the three reference problems and cross-cutting issues.

To come to a close, we would like to provide some conclusive remarks on the RDC and its conceptual approach. The three reference problems provided here are not to be understood in a mutually exclusive way, i.e. control issues relating only to control and not to change, aspects of change not to capacity-building etc. Instead, the three research areas are meant as analytical heuristics that highlight certain issues – without neglecting others – for the sake of interdisciplinary collaboration. Problems of control, as Smedberg and Light bring up in their introduction, are related to questions of agency and power, and ultimately to an 'ability to act or do' (p. 19), i.e. capacity-building. Greene and Schiffer, out of the stability/change section, refer to "*'actionable' human insight which is the foundation of 'design thinking'*" (p. 58). In empirical reality, all three problems of control, change and capacity-building occur simultaneously and intersect with each other, yet for the purposes of academic research, separation into three rather different vectors seems helpful, as this RDC demonstrates. Consequently, for the future of energy-SSH, we are confident that this collection builds a starting point for further *problem-driven* interdisciplinary research. Another attempt with more specific conceptual preparation and pre-selected authors has been made elsewhere (Büscher, Schippl and Sumpf 2018), so that there is a strong basis for advancements in this domain.

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