1 Introduction

Citizens in energy innovation and sociotechnical change

1.1 The changing image of energy citizens in sociotechnical change

Decentralized energy production based on renewable sources is a key change toward fossil-free-energy systems. This change is well underway in many countries, and the replacement of fossil-fuel-based solutions is increasingly taking place in the arena of mainstream deployment and adoption of renewable energy technologies. This means the “demand side” of the market plays a key role in the financing of change as well as in accepting changed consumption patterns and new technologies (IEA, 2018; IPCC, 2018). To many, this sounds a lot to ask given that present energy consumption is among the most passive and routinized forms of consumption there is.

Yet people on the demand side have in many countries taken the initiative (e.g., Ornetzeder and Rohrer, 2013; DeWald and Truffer, 2012; Nielsen, 2016), and when they do so they can do much more than just adopt and finance new solutions. Demand-side activities related to technological innovation, adaptation, new practices, and market creation have been found to be key “enablers” for the proliferation, further development, and mass-market uptake of low-carbon technologies, particularly regarding small-scale renewables such as heat pumps, pellet-burning systems, solar PV, and solar heat, which we examine in this book (Rohrer, 2003; Caird and Roy, 2008; Heiskanen et al., 2010; Nielsen, Reisch, and Thøgersen, 2016; Nyborg and Røpke, 2015; Ornetzeder and Rohrer, 2006, 2013). These findings and their importance run contrary to the mainstream climate and energy policies that have primarily targeted the “supply side” through subsidies, regulation, and supply-end investments (IEA, 2018; IPCC, 2018) and have sought to overcome “consumer barriers” using campaigns, means, and measures intended to better diffuse industry-developed products and improve their use (Mignon and Bergek, 2016; Nye, Whitmarsh, and Foxon, 2010). Consequently, there is a strong and growing interest to better understand citizens, as users, consumers, and civil-society actors, in energy innovation and transition processes (see, e.g., Smith, 2012; Ornetzeder and Rohrer, 2013; Schot et al., 2016; Meelen et al., 2019; Rohrer and Köhler, 2019).

This shift toward *active citizen contributions in sociotechnical change* resonates with wider research on users and consumers outside sustainability-related fields. Users were long seen as unlikely agents of technological change (Oudshoorn and Pinch, 2003). For instance, von Hippel and his colleagues have fought a 40-year uphill battle to establish the extent, depth, and significance of user innovation against incredulity from the prevailing innovation studies and policy paradigms that assumed producers and research institutes to be the only significant driving force of innovation (von Hippel, 1988, 2005, 2016). A similar gradual revelation has happened across neighboring disciplines and related topics regarding user participation in design (e.g., Schuler and Namioka, 1993; Voss et al., 2009a, 2009b; Jensen, 2012; Hyysalo et al., 2016a, 2016b), the active consumption of goods (e.g., Appadurai, 1986; Miller and Slater, 2007), and user alterations and redesigns in IT systems (DeSanctis and Poole, 1994; McLaughlin et al., 1999; Kohtala et al., 2020) and their roles in affecting broader sociotechnical change (Fischer, 1992; Kline and Pinch, 1996; Oudshoorn and Pinch, 2003; Williams et al., 2005; Hyysalo et al., 2016a).

A root cause for the long neglect of citizens in innovation and the gradual realization of their importance lies in the *invisibility of most citizen contributions to sociotechnical change*. Much of this invisibility can be described in terms of being *invisible work* in three senses: not being recognized as happening or being of importance, not being recorded and thus gradually lost to memory, and not showing up using the typical research instruments used by people studying the area (Strauss, 1993; Strauss and Star, 1999; Verheig et al., 2016). These forms of invisibility have entailed a need to develop specific and often rather arduous research designs in order to make the contributions visible (Suchman, 1995; Szymanski and Whalen, 2011; De Jong et al., 2015; Verheig et al., 2016). But these more detailed studies, in turn, are subject to counter arguments regarding over generalizations made on the basis a few, potentially exceptional, cases and sites. As a consequence, a considerable space for assumptions remains in regard to users' contributions and their importance to innovation and sociotechnical change. Given how hard it is to specifically identify the various forms of active citizen engagement in sociotechnical change, should the found instances be interpreted as being but the tip of the iceberg of a much more varied and plentiful contribution? Or is it more prudent and sounder to assume that the instances found may, in fact, be all there is?

The present book seeks to move research beyond making circles in this assumption space regarding *citizens in energy innovation and transitions*. As in many other fields, there are some exemplary works on particular citizen activities, such as on innovation (e.g., Rohrer, 2003; Ornetzeder and Rohrer, 2006, 2013; Truffer, 2003; Nielsen, 2016), on consumption (e.g., Nyborg, 2015; Juntunen, 2014a; Palm and Derby, 2014), on social movements (Smith et al., 2014; Hess, 2016; Kohtala, 2017), and on communities (e.g., Heiskanen, Johnson et al., 2010, 2015; Smith et al., 2016b). Yet, to date, they have only been connected by summative literature reviews (Smith, 2012; Durrant, 2014; Schot et al., 2016) and arguments made via non-sustainability-related historical

studies (Kanger and Schot, 2016; Kanger et al., 2018). The detailed evidence is also almost solely focused on the early phases of sociotechnical change and does not properly address the ongoing mass take-up.

The contribution of this book is thus to provide the first detailed, empirically grounded analyses of the activities that citizens engage in concerning sustainable energy innovation, community creation, and sustainability transitions and from the early stages of technological change to mainstream adoption. Methodologically, it elaborates the mid-range research design, the biography of practices and artifacts (BOAP) methodology, that can help achieve such analyses and further elaborate the import of the findings at a theoretical level through conceptualizing sociotechnical change as series of configurational movements that build on each other but change the character of technology and its userships while doing so.

1.2 Citizens in sustainable sociotechnical change—a short history of reconsiderations

The terms by which citizens' involvement in sociotechnical change have been addressed vary in different disciplines between user, consumer, customer, and citizen. Marketing and management typically talk of consumers or customers to emphasize the financial relations involved (e.g., Marchand, 1998; Prahalad and Ramasvamy, 2004). Design and computer sciences as well as innovation studies address the topic with the register of “user” that emphasizes the realized use and immediate benefits gained with it (von Hippel, 2005; Hyysalo et al., 2016), while social and political sciences tend to talk of citizens and consumers (Smith, 2012; Voß and Amelung, 2016; Hyysalo et al., 2016). The common denominator in these terminologies is that they denote people whose orientation to technologies is that of first-hand benefit or harm, or who become otherwise directly impacted by them. This is the functional opposite to producers and professional designers who engage in technological change primarily for economic gains made through sales (von Hippel, 2005, 2016; Bjerkness, 1987; Prahalad and Ramasvamy, 2004). Because of this, the present book uses the terms user, citizen, and consumer as partial synonyms and follows the nomenclature used in the literature that is being discussed, most commonly the “user” (unless there is a specific reason to stress one of the other terms specifically, such as when opposing consumers to organizational users or when emphasizing citizenship rights against mere using).

Historically, all the way up to the 1980s, users were largely seen as insignificant actors in technological change, and findings related to their contributions to innovation, design, and consumption were mostly regarded as idiosyncratic exceptions (e.g., von Hippel, 1976; Rosenberg, 1982; Bjerkness, 1987; Schwartz-Cowan, 1983). Research on technological change and innovation has since acknowledged the role of users but only gradually duly addressed it and discovered the range and extent it may have. This has taken place in several parallel disciplinary streams (for overviews, see Williams et al., 2005; von

Hippel, 2016; Hyysalo et al., 2016b), which have also gradually found their way into the studies of sustainable innovation and sustainable change.

By the 1990s, innovation scholars and sociologists of technology had recognized the importance of users (von Hippel, 1988; Klein and Rosenberg, 1986; Bieker et al., 1987), yet asserted that if users and other stakeholders have an impact on technology, they must have it before the form and meaning of the technology stabilize (Bijker, 1995; Noble, 1984). Once the technology's design and related infrastructure became locked in place, users' choices appeared to narrow down to adoption or non-adoption (Russell and Williams, 2002). Even within such constraints, users were observed to be active in several important ways, which can be characterized as *users having importance in early-stage innovation and shaping of technology, often through civil-society activism and local communities*:

- a) Users are the sources of inventive new technologies in areas where the available products do not cater to their specific needs. Even though further development often takes place in R&D companies, the lead-user designs spur on new product lines and improve earlier ones (von Hippel, 1976, 1988). In renewable energy, this has been found to be the case in wind turbines (Karnøe and Garud, 2012; Nielsen, 2016) and solar collectors (Ornetzeder and Rohrer, 2006).
- b) Users have been a vital source of information for developing new design versions as respondents to marketing research ever since the 1930s (Marchand, 1998). In sustainable energy this has been the case with passive houses (Rohrer, 2003; Ornetzeder and Rohrer, 2013).
- c) Users can act as design partners, as experts on their own work, and as design decision makers regarding the conditions of their everyday life (Bjerkness, 1987; Bødger et al., 2004). In small-scale renewable energy technology (S-RET), some evidence of this can be found in grassroots innovation (Smith et al., 2016a, 2016b; De Vries et al., 2016).
- d) Users also improve early designs through learning-by-using, both locally and through feedback to producers (Rosenberg, 1979, 1982; Lundvall, 1988; Lundvall and Vinding, 2005). In sustainable energy innovation this has been the case with solar heaters and woodchip burners (Ornetzeder and Rohrer, 2006).
- e) Early adopters have a strong influence on what direction uses of new technologies and social organization around them take, as well as on the norms governing them. This can affect potential alternative technologies and technology-related citizen activism as well as early phases of mainstream technologies (see, e.g., Bijker, 1995; Fleck, 1993a, 1993b; Flichy, 2007; Akera, 2001; Schwartz-Cowan, 1983; Fisher, 1992). In renewable energy such influence can be observed in the community energy movement as an alternative technological discourse (Hargraves et al., 2013; Smith et al., 2016b), as well as in how user experiments gradually led to the mainstreaming of wind turbines in Denmark (Ornetzeder and Rohrer, 2013; Nielsen, 2016).

- f) Users can also actively oppose or passively reject new technologies, or they can undermine their intended effects by failing to use them according to expectations (Akrich, 1992; DeSanctis and Poole, 1994). In S-RET this has been observed with added heating and cooling to passive house concepts in many countries (Ornetzeder and Rohrer, 2003; Palm and Derby, 2014).

The next set of reconsiderations emerged over the course of the 1990s, when the emergence of more flexible home and workplace information technologies made researchers realize that users alter and adjust technology-in-use more than had been assumed. The emerging more open and flexible development processes did not result in a similarly “closed” technology, as had been the case in the earlier mass-manufacturing era. The most important findings can be characterized as recognizing the *commonness of the active shaping of technology-in-use and cyclical development of technology*:

- g) Studies of home consumption revealed that instead of being passive adopters, ordinary consumers were active in adapting the configuration and meaning of the technologies to make them work (Silverstone et al., 1992; Lie and Sørensen, 1996). They were, by default, domesticating technology into the moral economy of the household and contributing to the long-term taming of new types of technology. Further research has since shown this to take place beyond ICTs (Miller and Slater, 2007; Berger et al., 2006). There is some evidence of the active domestication of sustainable energy solutions and even “domestication pathways” from one S-RET to another (Palm and Derby, 2014; Juntunen, 2014; Nyborg, 2015).
- h) Studies of workplace information systems showed that selective appropriation, integration into other devices, the co-evolution of practices and new technology, add-on solutions, new uses, (re-)inventions, and efforts to market the technology were, in fact, very common (see, e.g., DeSanctis and Poole, 1994; Alter, 2006; Szymanski and Whalen, 2011; McLaughlin et al., 1999). In sustainable energy such adaptation has been documented to some extent prior to the present line of study (Heiskanen et al., 2015; Raven et al., 2008; see Chapters 3 and 4).
- i) Home multimedia and workplace ICTs showed how more advanced peers, “warm experts,” were central in educating other users (Bakardjieva, 2005), as were semi-professional “local experts” who seconded their help in addition to their main jobs (Stewart, 2007; Voss et al., 2009), becoming “user-side innovation intermediaries” (Stewart and Hyysalo, 2008). In sustainable energy, user-side intermediation has been documented but seldom conceptualized thoroughly (Heiskanen, Johnson, et al., 2010; Raven et al., 2008, 2015; deVries et al., 2016; Meelen et al., 2019).
- j) It was further realized that many new technologies did not follow linear patterns where the design becomes “closed” before it starts to diffuse

(Fleck, 1993a; Williams et al., 2005) but involved *innofusion*, that is, iterative loops between design and use, often lasting as long as several product generations (Pollock and Williams, 2008; Hyysalo, 2010). Users' domestication and alterations can thus shape the technology, both at local adopter sites and through entering the many feedback loops that circle between suppliers and users. In sustainable innovation this has been discussed by Heiskanen et al. (2014) and under the headings of learning-by-using (Ornetzeder and Rohrer, 2013) and user assemblages (Nielsen, 2016).

The third and most recent reconfiguration in the understanding of the role of users in technological change has resulted in the rapid proliferation and sophistication of digital-sharing platforms throughout the 2000s and 2010s. The ensuing changes can be characterized as *user contributions becoming boosted through new digitally connected peer communities*:

- k) Previously unconnected users have formed communities of interest on the web that share and iterate designs. Such user-innovation communities have proliferated far beyond open-source software and are designing many products without suppliers (Tapscot and Williams, 2008; Jeppesen and Molin, 2003; von Hippel, 2016). In sustainable energy this has not been documented prior to the present line of study (see Chapter 4), but after our research others have identified it as well (Meelen et al., 2019).
- l) Manufacturers, in turn, are busy setting up their own user-innovation community efforts (Jeppesen and Fredriksen, 2006; Fuller, 2006; Pollock and Hyysalo, 2014). Living labs, web-based innovation areas, and user groups mark some of the widespread practices through which users are actively connected to each other and to producers in order to facilitate company research and development activities (Johnson et al., 2014; Leminen, 2015; Hyysalo and Hakkarainen, 2014; Mozaffar, 2016). This has not been reported in sustainable energy innovation to date, but is likely to emerge.
- m) User-configurable content and derivative designs have become more commonplace, particularly in social media applications, games, and mass-customized products (Benkler, 2006; Tapscot and Williams, 2008; Botero et al., 2010). In sustainable energy this has not been documented prior to the present line of study (see Chapter 3).
- n) Internet user forums, blogs, and discussion platforms have allowed users to pool their experiences and reveal their designs to other users. This has led to a "do-it-yourself renaissance," in which self-created and collectively created artifacts are gaining new impetus (see, e.g., Kuznezov and Paulos, 2010; Grabher and Ibert, 2014; Kohtala, 2017; Kohtala et al. 2020). In sustainable energy this has not been documented prior to the present line of study (see Chapter 3), but since then, it has also been recognized elsewhere (Meelen et al., 2019).

Taken together, these active roles by users underline that they can be a major contributing force, as well as an inhibiting force, for a given innovation and in long-term sociotechnical change. As can be observed from the above, the research that exists regarding sustainable energy has mostly concentrated on those types of contributions to innovation and sociotechnical change that were already well elaborated in the 1980s and 1990s in the wider academic community. Correspondingly, there is a relative neglect of the new patterns and opportunities that have opened up in this millennium. Also the empirical incidence and interrelations between the different contribution types need further research: do some types feed into others, place conditions, or inhibit others? And if so, by what processes? Thus far studies have targeted different technologies, different aspects, settings, and times in sociotechnical change and thus resulted in rather pathwork understanding of users in sociotechnical change that has high likelihood of biases.

1.3 A new approach to researching users in sociotechnical change

A new way to study users in sociotechnical change has been developed in the biographies of artifacts and practices (BOAP) approach (Hyysalo et al., 2019a). The BOAP approach entails a long-term serial ethnographic and historical study of sociotechnical change, in short, providing a mid-range methodology that is at once capable of zooming into activities, such as those by users, that are not flagged prominently in media or existing data sets and zooming out for longitudinal analysis of their importance in sociotechnical change. The methodology is further conducive to empirically grounded theorization and bridging different theoretical positions and empirical findings—particularly temporally and spatially more narrow or hollow depictions as we discuss in chapter 2 (Hyysalo et al., 2019).

In this book, the BOAP approach is developed further in order to address the patchwork and siloed nature of studies of users as in three research communities, those of *user innovation*, *sustainability transitions*, and *sciences and technology studies* (S&TS), which would all benefit from BOAP studies, albeit for different reasons. The aim of the book is thus as much substantive as it is methodological and aimed toward theorization.

User-innovation research has had pivotal importance in surfacing the amount of innovation made by users, and in doing so, showing how technological change is importantly affected by a range of actors and processes whose contributions remain invisible or shadowed by entrepreneurs and research institutes who (must) seek publicity for their commercial and research activities in order to be able to accomplish them (von Hippel, 2005, 2016). However, user-innovation research has limited itself to the invention and early commercialization phases and has been heavily disposed toward the study of new objects, be these physical or digital. This focus de-emphasizes users' other contributions to (often long and serial) innovation processes—such as new uses, new procedures, partial uses, collaboration with producers, and so

on—which typically accompany further innovations by users, as well as producers, and is an important dynamic to understand better (cf. e.g., Hienert et al., 2014; Hyysalo, 2009; Kohtala et al., 2020). Going further still, a wider cast of user activities involved in the shaping of sociotechnical change—such as adjustments to daily routines, recommendations, rejections, reclamations, lobbying, community building, and maintenance to mention a few—become cut off from the innovative activities of users. The picture of the forms by which they affect sociotechnical change, including the embedding of their innovative activities, remains incomplete.

The user-innovation researches focus (and its ensuing limits) is not accidental. It results from its orientation to establish the relative incidence of user and producer innovation under different conditions and the preference for variance epistemology and quantitative research designs to argue this case convincingly (von Hippel, 1988, 2005). Variance epistemology has, however, significant shortcomings in the analysis of contingent processes and emergent phenomena (van de Ven et al., 1999; van de Ven and Poole, 2005; Garud and Gehman, 2012), and the present book’s approach combines quantitated user-innovation research with detailed qualitative ethnographic work on user activities, as well as with process epistemology, in order to open up new substantive research and theoretical extensions regarding how users contribute to innovation and sociotechnical change.

Sustainability transitions research has recently emerged as a fusion point for understanding sociotechnical change. Its key contribution has been its ability to offer relatively clear starting and ending points for the study of sociotechnical change (Geels, 2002; Köhler et al., 2019). A focus on the sustainability of sociotechnical systems, premised on path dependency and interlocking of system elements, allows transitions research to outline a long-term change from one dynamically stable sociotechnical regime to another via different pathways, such as substitution or reconfiguration (Geels et al., 2016). Systems change typically lasts for decades and it provides a backdrop within which various innovations—as well as user contributions, their interrelations, and their relations to other actors—can be examined. In other words, the idea of transitions promises to provide a vantage point for “full cycle” analyses of how production and consumption interrelations change (Köhler et al., 2019).

However, owing to its roots in rule-governed systems and long time-span analyses (Geels, 2002; Köhler et al., 2019), transitions research tends to employ a distanced analysis of sociotechnical change in order to cover the width and length of the phenomena involved. Similarly to earlier innovation systems research (Lundvall, 1988, 2005), less visible actors and processes—such as users, learning, and knowledge building—are acknowledged as important but then treated in assumption-prone fashion and only at the aggregate level (for critiques, see von Hippel and Tyre, 1995; Tyre and von Hippel, 1997; Scott-Kemmis and Bell, 2010; Hyysalo, 2009; Miettinen, 2003; Mierlo & Beers, 2020; van Poeck et al., 2020). Consequently, the research and methodology needed to truly render visible such intra- and inter-actor processes remain decoupled from long-term change analyses. The present book elaborates a

research approach that can span careful site-specific studies covering long-term change in the sociotechnical change in question; thus, it holds the potential for emending this shortcoming in transition studies.

In contrast, *S&TS* excel in detailed ethnographic accounts of the complex and typically hidden aspects of sociotechnology. Its (material-social) constructivist methodology has been specifically developed for surfacing and accounting for contingencies and the emergent composition of objects, processes, and practices in context—in short, for providing a sophisticated process epistemology for studying sociotechnical change (Bijker, Pinch, and Hughes, 1987; Williams and Edge, 1996; Hess, 1997; Garud and Gehman, 2012). It thus provides resources for addressing the above-noted shortcomings in user-innovation and transitions research on users.

Yet, *S&TS*'s epistemic anchoring to ethnographically detailed studies of particular sites has tended to limit its yield in relation to characterizing sociotechnical change, both methodologically and theoretically (Hyysalo et al., 2019). Comparison and generalization across the patchwork of different sites, times, peoples, and technologies is a challenge to all innovation and technology analysis, but it is particularly thorny for constructivist *S&TS* epistemologies. Leading authors have concluded that *S&TS* rather provides generalizability through concepts that capture process patterns rather generalizability across comparable cases (Williams and Sørensen, 2002). The BOAP framework developed at the intersection of *S&TS* and innovation studies is a response to the quandary between the requisite specificity of studies and improved generalization. What is at stake is not pining back to objectivistic generalization but being able to better clarify how different sites, times and types of shaping technology matter in relation to each other.

Reflecting on these methodological underpinnings of the volume, Chapter 2 is devoted to expanding on the BOAP research approach. Regarding the ensuing theorization on sociotechnical change as *series of configurational movements* many of which involve users (as we discuss in chapters five and six), the focus on sustainable energy technologies is interesting because of the implied societal relevance and import to the everyday lives of large amounts of people. S-RETs are serious, even somewhat boring technologies that hold important capacity in relation to addressing climate change. These are not esoteric technologies—such as scientific instruments (Riggs and von Hippel, 1988) and rugged terrain vehicles (Hyysalo and Usenyuk, 2015). Neither are they mere playthings or sports equipment—such as windsurfing and kitesurfing equipment, mountain bikes (Lüthje, 2004; Lüthje et al., 2005) and rodeo kayaks (Hienert et al., 2014)—in which users have been documented to be in the driver's seat of technological change. Nor are they digital-only technologies that arguably have different patterns of change than their physical counterparts (Baldwin & von Hippel, 2011; Benkler, 2006). Thus as 'models organisms' for better understanding sociotechnical change S-RETs present different, and perhaps more convincing starting point, than many domains in which users have hitherto been shown to be of pivotal importance.

1.4 An overview of the volume

1.4.1 Chapter 2, “*Biographies of artifacts and practices in sociotechnical change*”

Sophisticated understandings of the technological change produced by innovation studies, transition research, and social studies of technology are, paradoxically, at odds with their own dominant research designs and the methodological guidelines. A key insight from the social shaping of technology research and process studies of innovation has been that new technologies are formed gradually in multiple, particular (albeit interlinked) settings, by many different groups of actors, over long periods of time. Nonetheless, common research designs have not kept pace with these advances in knowledge. The mainstream innovation studies continue to treat sociotechnical change through quantitated data series and statistical analyses (variance epistemology), which freezes the identity of each innovation and actors and organizations involved to just one point in time, while it is well known that all these tend to change in the course of innovation projects. Alternatives developed to better address the processual nature of change have resorted to intensive ethnographic engagements on particular sites or broad-stroke historical studies and systems analyses, yet have been unable to address both the intricacy of sociotechnical phenomena and the extent of the shaping process in tandem. To ensure that research is able to continue to provide grounded insight into the processes of innovation and sociotechnical change, this book argues for the ambitious reconceptualization of research designs. This would include a move from simple “snapshot” studies and broad-stroke “hollow” evidence to long-term research designs that progress through a weaving together studies in different settings, at different times, and with different granularities of analysis.

There has consequently been increasing interest in extending current methodological and analytical approaches through longitudinal and multi-site research templates. The BOAP framework deployed and taken forward in the present book builds on a 20-year-long body of studies in different sociotechnical settings. Chapter 2 outlines the rationale and basic principles of BOAP. It elaborates how they differ from more conventional methodological approaches in studies of innovation and diffusion through a detailed discussion of the interrelations between observation units, analysis units, and research questions. The chapter further elaborates the data and analysis methods in the BOAP study underlying the present book and elaborates its theory-building approach, which differentiates the methodology from naively inductive or deductive research orientations and methodology templates.

1.4.2 Chapter 3, “*Initial focus: user innovation in sustainable home energy technologies*”

The new millennium has seen an increasing interest in citizens as energy end-users. While much hope has been placed in more active energy users, it has

remained less clear what citizens are able and willing to do in shaping new technology. An investigation into inventions and modifications to S-RET conducted in Finland revealed a surprisingly high amount and depth of innovative activity. Over 200 inventions or modifications by consumers have been made to S-RETs, such as heat-pump, solar, and wood pellet-burning technologies. These inventions improved either the efficiency, suitability, usability, maintenance, or price of the S-RET systems. The analysis further clarifies that users are able to successfully modify, improve, and redesign almost all the subsystems in these technologies. The rationale for user inventions is based on the fact that supplier models do not sufficiently cater for the geographic location and house-specific variation in weather, material, aesthetic, and regulatory conditions, which leaves the local design space for users to improve their S-RET systems unexplored. In addition to expert evaluations, life-cycle carbon assessment was performed on selected user inventions, verifying their positive climate contribution.

The innovation activities of consumers support the proliferation of sustainable energy technology in contexts where institutional and technology characteristics are not yet fully developed for the wide proliferation of S-RET. Further analysis focused on how consumer-created technology solutions diffused. Their existence adds to solution variety, but do others adopt their solutions? The findings show that 2.7% of the consumer innovations diffused through commercial channels and 8.2% diffused through their straight adoption by peers. A significant share of projects (34.1%) were, however, part of “innovative peer diffusion” adoption that included adaptations and further modifications carried out among peers. Innovative consumers’ efforts to diffuse their solutions remain at a low level and indicate directions for platform development, by which these solutions may spread more widely. Taken together, the analyses counteract the false assumption that users can only make low-tech add-ons, as well as the equally untenable hope that citizen users could take over the design of renewables altogether if only given the chance and incentivized properly.

The actions of a typically small group of inventive users are embedded in and supported by the activities of a broader user base in internet communities, and it may be that the greatest importance of user innovators does not lie in the innovations themselves but in the sharing of competence that these inventive users do among peers (this topic is interrogated further in Chapters 4 and 5).

1.4.3 Chapter 4, “Broadening the inquiry: new internet-based user communities”

Users’ capacity to carry out their inventions (described in Chapter 3) owes much to their exchanges on *user-run internet communities*, a new and proliferating type of setting. The broadening of the focus to cover these novel internet communities is done in Chapter 4, pursued through ethnographic studies on the internet and in users’ homes. In internet forums, people organize

themselves around products and technologies in order to discuss use, purchasing, experiences, and community knowledge about products and producers (and so on). These online forums help otherwise dispersed and heterogeneous users to create a specific kind of *learning environment* that helps people to grow more knowledgeable of the technologies in question. The learning is carried furthest by inventive users, who also give back to these internet communities by providing deep-end peer support for other users.

From a systems change perspective, internet communities support the adoption and diffusion of S-RET. While internet communities are common far beyond energy technologies—their different forms can be found related to almost every serious technology and hobby area—they have become significant in S-RET diffusion and related systems changes in many countries and for many S-RET technologies. Their significance lies in that they qualify market information, articulate demand, and help citizen users to reconfigure the standard technology in order to meet the specificities of different local contexts. Such *user intermediation* and *market creation* activities are important in expanding the markets for S-RET beyond enthusiasts, environmentalists, and other early adopters. The early majority of adopters demand more exposure, clearer information, and less uncertainty about new technology options. The forums make the co-existence and interchange between different peoples, competences, and interests possible, which in turn becomes key in meeting the variety of market, institutional, cultural, and environmental conditions which S-RET faces in different contexts.

These internet energy communities are a new type of energy community that differs from the traditional local community energy that is premised on shared ownership and output, as well as distributed energy cooperatives. The nature of internet communities is that they are dispersed, and they do not center on shared produce but on sharing information, knowledge, and procedural advice. The dispersion over the internet allows these communities to bridge much wider geographical distances and their mass of participants allows for a plurality of orientations to coexist—offering a critical mass of competencies with which most problems can become clarified if not solved. These facets allow the new internet-based energy communities to form a “boundary infrastructure” among users that can perform the knowledge-related facets of energy communities more effectively and widely than the locality-based traditional forms. This also affects the nature of the discourse in the forums; instead of the critical and empowering energy autonomy-related discourse found commonly in energy communities, the discourse in (the successful) internet-based energy communities tends to foster what could be called “appreciatively critical” discourse on the focal technology. This discourse purposefully downplays general technology critique and ideological underpinnings in favor of naturalizing discourse, which opens the technical black box of technology and market functioning, but contains the scope of alternatives. This type of discourse appears to be rather effective in increasing the *legitimacy* of the focal technology in society.

1.4.4 Chapter 5, “Zooming out: user activities and the series of configurational movements in energy transition”

The chapter zooms out from the detailed studies of S-RET innovation and adoption and provides a longitudinal analysis of user activities in the proliferation of heat pumps in Finland. It does so through the BOAP approach and presents a new type of analysis in transition studies S&TS. The ethnographically detailed and historically extended longitudinal investigation on heat pumps in Finland spans from the beginning of the transition to the late acceleration phase, a considerably longer span than the previously detailed analyses on users in transitions.

The analysis shows that users have been active in adaptation and adjustment, user innovation, championing projects, forming user communities, user-side intermediation, market formation, and legitimacy building. These user activities primarily feed into each other and spur on the diffusion of S-RET. While most of the user activities shape the expanding technological niche to some extent, in particular, the increased adoption rates also affect other actors in the expanding niche, as well as related regime actors and the broader heating system landscape in a particular country setting.

The analysis in Chapter 5 questions the theory- and literature-review-based assumptions about particular user activities being associated with specific transition phases. Most user activities take place from the early upscaling phase to the late acceleration phase. While intermediation, market creation, and legitimacy building intensify from the take-off and early acceleration phase of transition onwards, this is particularly thanks to the emergence of the internet communities discussed in Chapter 4. Assertions of the relative importance or incidence of different user activities beyond this would not be warranted as their relative incidence, let alone importance, becomes next to impossible to study reliably.

The chapter further theorizes that the development and use of S-RET in each new country context should not be seen as a linear diffusion process or even a quasi-linear social-embedding process; it should be seen as an extended *innofusion* process, wherein technology, market, technology use, and governance characteristics evolve in tandem, typically riddled by an uneven pace of advancement and facing various hindrances. The importance of the innofusion view of transitions is underpinned by the fact that most transition to sustainable technologies in most countries and regions are, necessarily, early or later followers, and not taking place in globally early settings. Ironically, the dominant transition models are anchored to broad-stroke histories and detailed studies of globally early settings in sustainable change, which are in fact be rather poor “model organisms” for understanding how the majority of transitions play out on the ground in specific countries, areas, and locales. The analysis of the early-follower country context of Finnish heat pumps opens questions as to the adequacy of transition models for the logical majority of settings.

1.4.5 Chapter 6, “Conclusions and implications for management and policy”

The concluding chapter spells out the overall importance of the analyses to the three theory traditions motivating the book, namely innovation studies, transition studies, and S&TS. The importance of users in sociotechnical change is not limited to just providing variety in technological solutions at the onset of sociotechnical change, to then be exploited or discarded by the market as a selection environment. Instead, we see continued user-innovation and peer assistance that goes into tailoring the technology to new settings in which it becomes gradually adopted. The influence of users reaches beyond inventions into competence building and peer-to-peer interaction, providing wide support for adoption and adaptation and other user intermediation, legitimacy building, and market creation.

Internet communities allow for the plurality of user orientations to come together and feed into each other. They provide a wide reach that is independent of physical locality and access-time coordination: it is these capacities that render them effective new energy community forms. This stands in contrast to community energy and innovation communities that are unlikely to grow into substantial forces for multifaceted sociotechnical change unless they grow into diverse and trans-local coordinated movements. Their limitations for doing so have to do with the confines set by space and uniformity of orientations and competencies with respect to “serving” tens of thousands of diverse peers.

Overall the importance of users in sociotechnical change is best theorized as being comprised of a series of configurational movements that gradually congeal sociotechnical relations into increasingly stable objects and market relations. Such an extended inno-fusion process provides an alternative account of sociotechnical change to that of social-embedding and generic-transition models that have assumed relatively stable technology characteristics and adopter identities after the early pre-development phase.

The concluding chapter further elaborates what it would mean to move to more user-driven energy business and energy policy. The current actions energy companies and energy technology companies flag as “customer-centered” and “user-driven” mostly just tune their offerings *to* the customers in a manner that has long been regarded as business-as-usual in most other sectors such as ICT. Deeper user orientation would follow from business and policy geared to work in partnership *with* consumers in realizing more ambitious low-carbon solutions and yet deeper user-driven orientation would depart from the actions already taken *by* consumers to develop radical business and policy actions.