5 Zooming out

User activities and the series of configurational movements in energy transition

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5.1 Introduction: transitions as a potential framing to integrate different user contributions to sociotechnical change

The idea of sociotechnical transitions may hold the potential for integrating and examining the interrelations between different user contributions in long-term sociotechnical change. Transitions research examines the long-term change in sociotechnical systems under the conditions in which consumption and production patterns are ingrained in existing structures (Geels and Schot, 2007; Köhler et al., 2019). Under such conditions, the often radical changes needed to increase environmental sustainability face the inertia of existing sociotechnical regimes. Regimes feature shared rules and the intertwinement of the technology base, scientific research, logistics, raw materials access, investments, regulation, and consumption patterns, which have formed strong path dependencies and efficiencies through decades of sunken investment and learning effects (Rip and Kemp, 1998; Geels and Schot, 2007). In transitions research, systems change is seen to be possible through the destabilization of dominant regimes by landscape pressures and the gradual technical, economic, and sociotechnical maturation of alternative solutions in niches, which are partially protected from the full selection pressure of the market (Geels, 2002; Geels and Schot, 2007; de Haan and Rotmans, 2018).

Transitions are seen to follow a progression of stylized phases, beginning from the *pre-development and exploration phase* where small-scale experiments for new alternatives take place, but no visible change happens in the regime (Hoogma, 2002; Geels and Schot, 2007; Safarzyńska et al., 2012). The *take-off phase* follows, wherein the alternative technology develops into a niche, with more developed technical characteristics and market availability, and gradual agenda building around the niche (Safarzyńska et al., 2012; Geels and Schot, 2007). The next phase is the *acceleration and embedding phase*, during which niches expand and become mainstream markets that start to compete with the incumbent regime, which then begins to react to the niche (Kanger and Schot, 2016). The expansion of the adopter base is associated with structural changes in markets and institutions, and with the continued development

of technological solutions, gradually improving their economies of scale (Safarzynska et al., 2012; Kanger et al., 2018). The final phase is *stabilization*, marked by the decreasing speed of sociotechnical change as a new dynamic equilibrium is reached, and it becomes easier and more routinized for adopters to make a choice in the new regime than in the old (Geels and Schot, 2007; Schot et al., 2016; Geels et al., 2016).

Ambiguity remains regarding the markers of transition phases. Geels and Schot (2007) tie the acceleration phase both to innovation diffusion theory (Rogers, 2010) and to the point when the diffusion curve becomes self-sustaining, implicitly cast somewhere between 5% and 20% of the total cumulative adoption. Some authors denounce the split between pre-development and take-off (Schot et al., 2016; Kanger and Schot, 2016), while, for example, Meelen et al. (2019) claim to study the acceleration phase at the point of less than 2% e-car diffusion, implying that if other systemic properties were sufficiently in place, acceleration could be seen to take place much earlier despite low cumulative adoption. Reflecting on this high variance, the transition phasing is perhaps best seen as a useful means for the indicative comparisons of the stages of system change in different contexts, rather than providing strict operationalization thresholds.

The benefits of transition framing, and the reason why it was used in the present study, are that it connects the technology proliferation to the advancing technology and market characteristics, and thus holds the potential for clarifying the interconnections between the various activities that adopters perform in the course of sociotechnical change (Heiskanen et al., 2014; Schot et al., 2016; Kanger et al., 2018). As noted in Chapter 1, the capacity to connect different aspects of user activities is important as several fields have contributed to understanding different aspects of how user activities may contribute to sociotechnical change (McLaughlin et al., 1999; Hyysalo et al., 2016a; Kohtala et al., 2020). The economics of innovation and innovation systems have long recognized the importance of producer–user interactions (see, e.g., Rosenberg, 1982; Lundvall, 1988), and included users among the actor groups that affect innovation systems via shaping the selection environment, market creation, and direction of search activities (see, e.g., Freeman, 1979; Weber and Rohrer, 2012; Bergek et al., 2015). Yet to understand in more detail *what* and *how* users contribute to sociotechnical change, several related disciplines and strands of innovation studies provide greater detail and clarity.

The proliferation of new technology is not reducible to the communication of unchanging goods in undifferentiated social systems (Rogers, 2010) but involves changes in the composition of goods, markets, and the institutional environment (Mackenzie and Wajkman, 1999; Sørensen, 1996; Williams et al., 2005). The adoption process is qualitatively different for the adopter segments that follow the early, typically technologically savvy, adopters: the requisite signaling of availability, the social legitimacy of adoption, payback characteristics, observability, the understandability of the new solution, and the ease of adoption all need to be at a higher level in order for the

later adopters to adopt—the technology and market may have to change substantially in order to spread to new segments (Rogers, 2010; Moore, 2001; Cockburn and Ormrod, 1993; Williams et al. 2005). Transitions literature acknowledges these qualitative shifts in adoption through its emphasis of institutional, market, and technology change in the “societal embedding” associated with acceleration phase (see, e.g., Hoogma et al., 2002; Kanger et al., 2018; Meelen et al., 2019), but this and the user activities associated with it merit closer attention.

Further, as discussed in Chapters 1 and 4, taking goods into use often involves not only adoption but also *adaptations*, such as resignifying, repurposing, adding to, modifying, redesigning, and intertwining the goods with other artifacts, physical contexts, and everyday practices (de Sanctis and Poole, 1994; Juntunen, 2014a; McLaughlin, 1999; Silverstone and Hirsch, 1992; Kohtala et al. 2020). Adaptation can increase the adoption of innovation by making it possible to adjust it to the cognitive, social, and material needs of the adopter (Agarwal, 1983; Fleck, 1993a, 1993b; Rogers, 2010). Indeed, the applicability of off-the-shelf small-scale renewables to a given adopter site varies owing to region-specific variations in housing, climate, and regulation, as well as to the building location, housing type, and homeowners’ everyday practices (Judson et al., 2015; Juntunen, 2014a; Nyborg, 2015). Adaptations are often paired with various forms of *championing* complex projects, new installations, and information gathering (Klerx and Aarts, 2013; Martiskainen and Kivimaa, 2018).

As discussed in Chapter 3, some users may become innovators themselves. Research on the early phases of an energy transition has underscored the importance of citizen groups working as activists and innovators, initiating niche development in wind turbines, solar collectors, low energy housing, and alternative building types (Ornezeder and Rohrer, 2006, 2013; Truffer, 2003; Seyfang, 2010; Nielsen, 2016). Some of these civil-society initiatives have fueled mainstreamed development activities while others have remained local, critical endeavors for alternative ways of future life (Hargreaves et al., 2013; Smith et al., 2014, 2016b). As we learned in Chapter 3, innovation by users has also been found in the acceleration phase of transition in line with innovation being found among the general consumer population (von Hippel, 2016).

Throughout Chapters 3 and 4 we saw how adoption, adaptation, and innovation processes were amplified by peer intermediation and peer communities. Again, transitions research has mostly concentrated on community groups and movements that are united by an ideological commitment to alternative technologies and are typically geographically local (e.g., Smith et al., 2016b). But, as discussed, there are also increasingly important communities that are native to digital settings that connect the geographically separated peers of alternative technologies (Hyysalo et al., 2018; Meelen et al., 2019).

Transition research has further emphasized advocacy and political participation by citizens as key civil-society contributions to transitions, following

earlier work on social movements and in science and technology studies (e.g., Smith, 2012; Jørgensen, 2012; Hess, 2005). This emphasis is, on the one hand, due to the fact that most energy- and mobility-related societal developments are intertwined in political decision-making, either in preserving the status quo or in deciding to favor alternatives that are typically initially more costly and uncertain, such as the potential of wind and solar energy up until the late 2000s (Rip and Kemp, 1998; Hoogma et al., 2002; Truffer, 2003; Smith, 2012). On the other hand, tying citizen participation to political processes is due to an association to the environmental movement, which has been common in the early years of the formation of many sustainable niches (see, e.g., Ornetzeder and Rohracher, 2013; Hess, 2005).

Research aiming to clarify actor roles in transitions have been common (e.g., Farla et al., 2012; Bergek et al., 2015; deHaan and Rotmans, 2018), but there has been less than a handful of studies that focus specifically on civil society and users in the course of transition and that are not limited to a temporally and spatially limited snapshot. Smith (2012) reviewed the literature on traditional civil-society-influencing mechanisms for energy transitions. He views grassroots innovation, citizen science, and green consumption as early niche-supporting processes that lead to the following: the community-led upscaling of innovation; consumer boycotts, protests, lobbying, counter-expertise, and standard creation as regime-destabilizing forces; awareness raising and social pressure as landscape-level pressuring processes; and community aspirations and the emergence of plural visions in civil society as processes falling between matured niches and the incumbent regime. Smith further illustrated how civil-society action could have substantive, procedural, and structural destabilizing effects. While Smith focused on civil-society activities, Schot et al. (2016) phrased their review in terms of users, potentially expanding the scope from the various forms of civic activism to cover all the affected people on the demand side of the transition. They propose a sequence where “user-producers” and “user-legitimizers” create technological and symbolic variety during the start-up phase, “user-consumers” integrate the solutions into their everyday lives, together with “user intermediaries” who align various actors during the acceleration phase while increasing the amount of “user-citizens” who mobilize against the prevailing regime, hollowing it out, causing ever more consumers to choose the emerging regime. In this schemata, civil-society roles are clustered under the roles of user-citizens and user-legitimizers, and direct engagement with technology falls under the roles of user-producers and user-consumers.

The invisibility of most citizen and user contributions, as discussed in Chapters 1 and 2, is a particular problem for transitions research. Transition studies are most commonly conducted based on document analyses, surveys, and expert interviews in order to cover the often long and wide change processes (Zolfagharian et al., 2019; Murto et al., 2020). But experts in industrial fields are seldom aware of the work done by users beyond individual instances, and thus users’ activities tend to remain invisible to them (von Hippel, 2005,

2016). Surveying tends to focus on actors seen as central in the industry, and it would indeed be difficult to target an undifferentiated mass of people for improvements without specifically devised representative surveys (De Jong et al., 2015). Some of the reasons for non-visibility can also be more blatant, such as supplier companies denying the primacy of functional user design due to its crudeness (von Hippel, 2016). All in all, while users attract much interest across disciplines, they are difficult to study systematically from historical materials or through other arm's length approaches; for instance, by running expert interviews at the supply-end or governmental agencies.

The above reduces transition research to a two-sided position regarding user contributions to sociotechnical change. On the upside, transition framing could integrate the diverse research streams on the forms of user contributions to long-term sociotechnical change. On the downside, the methodological grounds by which transition studies have been pursued may remain inadequate for the task, having a tendency to fall towards 'hollow' depictions criticized in chapter 2. BOAP research holds potential to improve the situation by providing both detailed and temporally extended research against which more site- and time-limited studies can be compared and against which theory building can progress without making sweeping model-based assumptions.

With this aim, we outline the Finnish heat-pump transition for the heating of detached houses (Section 5.2) and integrate the evidence given by the BOAP sub-studies for the roles that users have played, and we then give a detailed elaboration of each of the observed roles (Section 5.3). We proceed to present a more fine-grained model of local transition as a series of configurational movements (Section 5.4) and finally discuss the findings against previous theory building (Section 5.5). In doing the above we have complemented our studies with the historical analyses of heat pumps in Finland during 1978–2015 conducted by Heiskanen et al. (2017a) and Lauttamäki (2018), and other research into heat pumps (e.g., Heiskanen et al., 2011; Martiskainen, 2014). For more details on data and methods, as well as the Finnish country context, see the Appendix of this book.

5.2 The heat-pump transition in Finland and evidence of user contributions in different phases, 1980–2018

Heating of interior spaces in Finland has featured a varying mix of burning oil, solid wood, coal, gas, and peat, heating along with direct electricity, and the recent rise of heat-pump has produced additional energy. For residential detached houses, which comprise an average of roughly 70% of the present Finnish housing stock and which are the subsection of space heating in which we examine heat pumps, the last 50 years comprise a sustainability transition from the fossil fuel dominance of the 1970s (accounting for 80% of space heating energy, the other 20% being covered by the small-scale combustion of

wood) to a “remnant problem” of the last 10% of fossil fuel heating in 2020 amid a more varied energy palette.

Out of the newly built detached houses, 50% are today equipped with a ground-source heat pump (GSHP) and an estimated 20% have some form of air-source heat pump (ASHP) as the prime heating source;¹ district heating, solid wood, and direct electricity cover the rest. Heat pumps have also been the most popular retrofit option, and currently over 1 million heat pumps are in operation in Finland, both as primary and secondary heating sources in approximately 1.4 million applicable buildings, even though the heating retrofit cycles are slow and the transition will thus continue for some time to come. Along the changes in adoption the transition is associated with the changing of key production and retail-side actors from oil to heat-pump associated ones, changes in taxation, technology development, and other institutional changes. The development has been mostly market based, only minor household and energy renovation subsidies have been in place since the 2000s.

In a recent European comparison, Finland is among the countries, in which relative household energy prices favor electricity and heat pumps over gas and oil, and in many of which heat pumps have also diffused widely (others being NO, SWE, AT, CZ, LT, FR, PT, and NL) (EHPA, 2018). In contrast, in countries where gas, oil, or district heat prices have been consistently lower than electricity prices, and thus the overall heat-pump produced energy price has been less favourable, only a modest heat-pump uptake has taken place (GE, UK, BE, IT, DE) (EHPA, 2018). (See the Appendix for more details on the Finnish energy sector, energy policy, and market conditions for heat pumps.) These relative energy prices have been relatively consistent over the years and are good to keep in mind when considering comparability as countries with low gas and oil prices continue to feature an economic environment where the heat-pump transition is not helped by relative energy prices.

Finland was among the early-adopter countries of commercial heat pumps in the wake of the oil crises in the late 1970s and early 1980s (Heiskanen et al., 2014, 2017a; Lauttamäki, 2018). The early installations were GSHPs with horizontal heat collector systems on the land or in water reservoirs, built by plumbing and coolant companies that diversified into the domain. The early Finnish market development featured several companies, and by 1985 roughly 12,000 units had been sold to house owners and to various small and medium-sized businesses (Lauttamäki, 2018; SULPU, 2018). In the media, heat pumps were predominantly discussed positively, albeit they were the target of incumbent attacks during the course of the 1980s (Heiskanen et al., 2017a). The nascent industrial field featured little organization or domestic research, and various quality problems riddled many early installations. Yet the market developed positively with relatively competent pricing until the oil price decreased dramatically in the mid-1980s. Once the cost drivers for adopting heat pumps against the then-current and projected energy prices disappeared, the sales stalled and the field entered a death spiral. Companies gradually quit

and maintenance and customer problems were left unresolved, leading to a tarnished reputation and the cessation of commercial activities by the 1990s (Lauttamäki, 2018; Lauttamäki and Hyysalo, 2019). All in all, this pre-development and nascent take-off did not alter the position of the oil-based and direct electricity heating regime in the Finnish residential housing sector.

There is scant research evidence on user roles in this early development period. Some users acted as advocates of heat pumps in public media and many more must have championed the new technology in their own buildings in order to have the heat-pump systems implemented successfully given the state of the product offerings available at the time. Most importantly, there were 12,000 early adopters whose purchasing decisions fueled the birth of the industrial field; yet, after the oil-crisis shock, the rest of the citizenship no longer followed.

The Finnish heat-pump field rose from the ashes in the mid-1990s owing to the continued expansion and development of the field, particularly in neighboring country Sweden (Zogg, 2008; Dzebo and Nyqvist, 2017). The heat-exchanger equipment was now more standardized and reliable, the newly developed vertical borehole and collector technology made adoption possible for a far greater number of people and locations (as one no longer needed access to a water reservoir or a large land area) (Heiskanen et al., 2014, 2017a; Lauttamäki, 2018). The suppliers organized themselves under industry associations (the Finnish Heat Pump Association [SULPU] and the Finnish Borewell Association [Poratek]) in order to provide training, monitoring, public lobbying, and a voice in the energy field. Associated with steadily rising oil prices and environmental taxes on oil and electricity, GSHP installations started to re-emerge in the residential retrofit and newly built markets after 1995. At the same time, some older, early 1980s units began to be withdrawn (Heiskanen et al., 2014, 2017b; Lauttamäki, 2018).

ASHPs were also introduced as heating devices in the late 1990s, after being used for cooling in warm climates (Lundqvist, 2008). While there were doubts about the energy saving they would provide (Heljö and Laine, 2005), ASHPs were inexpensive, ranging from mere hundreds of euros to €2000–3000 (in contrast to the €15,000–30,000 cost of GSHPs), were more straightforward to install, and had a quick return on investment, even if they might not work well as a primary heating source mid-winter. ASHP sales rapidly increased to over 40,000 units sold annually since 2005. By the mid-2000s, heat pumps had proliferated to roughly 5% of the estimated 1.4 million buildings that they could apply to in Finland (Hyysalo et al., 2018).

In transition terms, the years from 1998 to 2005 are best periodized as a (new) take-off phase that gave way to an acceleration phase around 2005 (see Figure 5.1). In terms of indicators for the phases, technology development happened elsewhere to the extent that by 2000, both GSHP and ASHP systems were again cost-competitive in the Finnish market. Installation numbers rose rapidly among early adopters up to 2005, after which a market development stabilized to roughly 50,000 units sold annually. Adoption moved beyond early

Figure 5.1 The cumulative number of heat pumps in use during the take-off and acceleration phases of transition. Source for the statistics on heat-pump cumulative amount: SULPU ry.

adopter segments between 2005–2010 for all heat pump types. In terms of institutional development, the industry associations emerged in the late 1990s, and amount of resellers rose as well, including the largest hardware store chains by the 2010s. User communities also emerged and changed, as we detail in chapter 4. These aspects of the technological niche build-up followed each other so that a mature niche was in place around 2004–2007, with, as yet, few changes inflicted on the heating regime.

There is more evidence of user activities in the 1995–2005 period thanks to the archives of the peer-to-peer internet discussion forums discussed in Chapter 4. Some users championed installations and passed on information about heat pumps in their local networks. Internet forum discussions reveal considerable efforts by prospective consumers to assess the yield and payback times of GSHP systems due to uncertainties related to boreholes at the time. Also, installation, maintenance, and repairs were discussed among peers, showing intermediation in local settings and, with the spread of internet forums, also nationwide. Innovations by users in heat pumps became actively revealed in

internet discussion forums following the introduction of first forums in 2004 and 2006, indicating that innovation activities by users were already underway earlier (Hyysalo et al., 2013a, 2013b, 2017).

Given the above we periodize that the acceleration phase in Finnish heat-pump transition started between 2005–2007. While the annual installation numbers stabilized in 2006, the early acceleration phase still featured many uncertainties for both technology and the market, as discussed in Chapter 4. The trustworthiness of supplier information and the reliability of installers were still ambiguous, and making an informed decision was time consuming (see Chapter 4). Also, as late as 2010, some experts expressed doubts about whether ASHPs actually saved energy in real buildings due to the low coefficient of performance being further decreased by wall partitioning indoors. In contrast, toward the end of the acceleration period in 2017–2020, few such doubts or market difficulties were present. Purchase comparisons could be run in a matter of hours in internet forums, and the education and experience of the installers and resellers had improved. Resellers now included the largest hardware and electronics retail chains. The industrial field on the whole had become recognized and its industry association, SULPU, was active in field-internal development and national energy policy.

Also technology characteristics for cold country contexts had advanced for both GSHPs and ASHPs. For ASHPs the models for cold climates advanced to such an extent that a positive energy yield was retained with temperatures under -20°C , in contrast to the early range of -10°C to -15°C . Also, new user practices had stabilized; for instance, it was now an accepted practice that many ASHP adopters kept their former primary heating system—be it oil, direct electric heating, or solid wood—and only used it for the lowest temperatures, whereas they used the ASHP for 80–90% of days in the heating period when its efficiency was good.

All in all, the uncertainties and ambiguities surrounding heat pumps in residential housing mostly dissolved, apart from use in very unusual settings. With GSHPs the drilling technology advanced and grew cheaper to the extent that boreholes could be extended cost-effectively to 300 meters, compared with the initial 60–80-meter levels, which allowed the scaling up of GSHPs to cover 100% of heating needs from the typical early 80% that left uncertainties about sufficiency. The Geological Research Centre of Finland modeled the ground-source heat potential across the country, aiding planners' and property owners' decisions about GSHPs (Lauttamäki, 2018). During the acceleration phase, both ASHPs and GSHPs became mainstream and were normalized in the Finnish heating market. Both benefited from increasing landscape pressure from climate change in terms of cultural values, and they also directly benefited from rising energy costs and taxes on fossil fuels. Heat pumps also benefited from neighboring niches, such as the proliferation of underfloor piping, that provided better efficiency for GSHPs.

Evidence of several user roles in the acceleration phase development is abundant. The most decisive action is the adoption of over 600,000 heat

pumps, which in turn incentivized the resellers, manufacturers, industry association, and vocation training to invest in the developing heat-pump field. Many users were active in adjusting the technology to their particular houses, heating systems, and daily practices, and respectively adapting their heating practices and contexts to the heat-pump technology (Heiskanen et al., 2014; Juntunen, 2014b; Hyysalo et al., 2018). Also, DIY projects prospered, including next to 100 user innovations as we detail in Chapter 3 (Hyysalo et al., 2013a, 2013b, 2017). Some users in local communities, as well as in internet communities, acted as champions to aid heat-pump use and proliferation (Heiskanen and Lovio, 2010; Hyysalo et al., 2013b, 2018; Heiskanen et al., 2014), associated with the growth of user communities, out of which there is sporadic evidence of local communities playing a role in the early years of acceleration and strong evidence of internet communities playing a substantial role across the period (Hyysalo et al., 2018), also as user-side innovation intermediaries (Stewart and Hyysalo, 2008) who aid diffusion (Mignon and Bergek, 2016). Regarding market formation, and the purchase and selection of equipment, the internet discussion forums were important in storing and updating the technology, product, and market information in the changing field and in curbing substandard installations or misleading sales (Hyysalo et al., 2018).

In terms of periodization, the acceleration phase is characterized by the extending and gradually stabilizing resales points and offers, suppliers serving the field, media publicity, user practices and communities, research inputs, the beginning of vocational training, and the maturing of technology characteristics. Between 2006 and 2017, the heat-pump stock grew from 80,000 to 750,000 (i.e., from 6% to 55% of the maximal diffusion).

From 2017 and ongoing, the residential sector market's heat pumps have begun to enter the stabilization phase, where heat pumps become the dominant option in the market (see Figure 5.1). As noted above, by 2019 no less than 70% of new detached houses in Finland were equipped with a heat pump as the primary heating source. The replacement rate of oil heating in retrofits with GSHPs or air-to-water heat pumps also continues steadily, as do installations of ASHPs into direct electricity heated homes. The national climate policy targets rely on heat pumps substituting the last fossil fuel consumption in detached housing. In public media and everyday discussion, heat pumps in residential houses no longer appear as a novelty, and their further proliferation appears to proceed as a self-evident matter, sales remaining at a steady or rising level with new annual sales records appearing every now and again (SULPU, 2018).

The stabilization of heat pumps in detached housing is further paired with larger-scale heat-pump systems starting to take off in the large building and district heating markets (Lauttamäki, 2018), but as this niche concerns a different ecology of actors than the residential sector, we do not examine its development here. Regarding present user activities we see steady adoption, adaptation, and some DIY still displayed in non-standard housing contexts, as well as

the intermediation taking place. The market and legitimacy characteristics are well developed.

All in all, the GSHPs and ASHPs have followed a substitution pathway (Geels and Schot, 2007), displacing oil and direct heating as the dominant heating systems in residential housing (Lauttamäki & Hyysalo, 2019). A subset of ASHPs in hybrid heating configurations follow a reconfiguration pathway wherein they are added-onto the mix of existing heating equipment that is based on solid wood and remnant oil heating. The effect of heat pumps on the detached housing heating market has been that the formerly dominant fossil fuel-based heating, technology providers, and fuel suppliers have given way to the dominance of heat-pump and electricity-related technology and market players.

5.3 Clarifying the user activities related to the Finnish heat pumps

We now move deeper into user activities in the Finnish heat-pump transition. We elaborate them in more detail and better spell out their interrelations and importance to transition. We do so by departing from adoption and routine use, moving to adjustment and adaptation, and onwards to the championing of projects and innovation by citizens, all of which are primarily conducted by individuals, even if often helped by peers. We then elaborate on communities and intermediation, which take place both locally and digitally, and finally discuss market creation and legitimacy building, which appear foremost as the aggregate effects of large digital communities even though some of these activities take place without individuals being digitally connected. All in all, the Finnish heat-pump transition thus features a blending of the ways by which users' have been seen to shape the sociotechnical change covered by three generations of research we outlined in the introductory chapter.

Adoption and routine use are the most common and most important contributions that citizens make to advance transition. They do so not only as "consumers" making buying decisions but also as people sustaining the use of heat pumps and integrating heat pumps into their everyday living practices and sustaining a predominantly positively tuned discourse with the people they encounter. Heat pumps presented not only a new heating technology but also a new type of warmth. This is most pronounced with ASHPs that rely on an air convector to transmit the warm airflow into space. There is audible noise from both the convector and the outdoor collector unit that is associated with the periodic burst of warm air, which stirs indoor air into motion. The air typically needs to be blown from above to effectively spread into the space. The distribution of heat through air mixing is a different type of warmth than that which Finns are accustomed to from their earlier heating forms. Solid wood stoves or radiators below windows (be these water or direct electricity heated) provide point heat and radiation, which is typically experienced as pleasant and, in most

cases, is distributed around the house in such a way that closed doors or other partitions do not affect it. It is not trivial that such new conditions of comfort are adopted and accepted in everyday living and that positive word of mouth and public discourse accompanies them. GSHP systems were more compatible with radiators or underfloor heating, but for these systems adopters faced a considerable €10–20k investment and, in the early phases, still needed to trust a system that scaled to 60–80% of the maximum heating need in order to save in the upfront costs.

We have also stressed that even before people got to experience heat-pump usage, they needed to invest time and effort into the purchase process—scaling, comparing, selecting, planning, and overseeing installation—and the effort required for making an informed choice was considerable in the early stages of heat-pump proliferation. It could have taken days or weeks of part-time work, depending on the thoroughness of the decision and the particularities of the installation. On top of this, even routine use requires occasional maintenance.

Adoption and routine use also concern by far the greatest population: with over a million installations, heat pumps touch the lives of a third or even half of the Finnish population of 5.5 million. The simple adoption numbers also concern the greatest leverage point for the transition: the investment that has gone into the Finnish heat-pump field to date is €4 billion, which has enabled the 4000 people in supply, retail, installing, maintenance to work in the field and to improve their operations. It has further legitimated energy counseling, educational programs, and (modest) tax deductions along the way. The simple purchase amounts have also been a clear signal to heat-pump manufacturers who have further developed their offerings to better match cold-climate contexts with significant improvements in the two decades of heat-pump transition in Finland.

Yet, as we have argued, adoption has not been automatic and has been importantly supported by other user activities, particularly with respect to moving heat pumps from early adopters to later ones, who were predominantly less motivated by environmental choices or technical novelty and had less interest and ability to conduct their purchase and adoption decisions. Adoption remains modest in early transition stages and the rise in sales number was associated with other, arguably more intensive, user engagements with new heat-pump technology.

Adjustment and adaptation have been common in getting routine use going. Most users have had to make some changes to their daily habits regarding, for instance, keeping room doors open, changing furniture layout, or changing routines related to emptying iced-up meltwater from the heat pump. Installing the heat pump in a particular house is typically also a process where adaptations and compromises have to be made regarding the aesthetics of the indoor space and the outdoor appearance, and the effectiveness of the heat emanating from the convector unit (Heiskanen et al., 2014; Hyysalo et al., 2013b; Jalas et al., 2017). Notable discrepancies between factory values and the yield in real, site-specific use at different temperatures have been

presented by resellers and have prompted many users to monitor their equipment more carefully and to consult their peers and resellers regarding if and how the yield can be improved through changing the settings or through small hacks (Hyysalo et al., 2013b, 2018).

Evidence of adjustment and adaptation can be found in all transition phases (see, e.g., Motiva, 2010, 2012; Hyysalo et al., 2018; Lauttamäki, 2018), but to estimate its proportional incidence in different transition phases and the expense of time and effort used on it would require devising a representative survey (akin to the survey conducted by De Jong et al., 2015) or a representative wide-scale interview study on heat-pump users, administered at a set time after implementation and updated longitudinally (akin to the study by McLaughlin [1999] but applied to hundreds of people with an arguably difficult-to-establish sampling frame).

Innovation by users is documented from the take-off and acceleration phases. As documented in Chapter 3, hundreds of DIY projects were pursued by consumers, and while over 400 of them were verified as having some novelty and benefits by domain experts, 113 of these projects turned out to be new-to-the-world innovations (Hyysalo et al., 2013a, 2013b, 2017; Mattinen et al., 2014). As noted, these innovations mostly emerged as responses to local particularities, which remain poorly catered for by commercial models that seek to appeal to common denominators of wider user populations and thus, for instance, sacrifice potential energy gains for the sake of added safety and reliability. The user innovations introduced solution variety, both to technological offerings and new uses, but their verifiable diffusion, and thus their realized variety, remains more modest: in Finnish S-RETs, 2.7% become commercialized, 8% are copied by peers, and 34% are fed into further DIY projects as a part of further solutions (Hyysalo et al., 2015, 2017). Yet, as discussed in chapter 4 user innovations have had another important contributory capacity: the innovation and DIY projects and the peer-to-peer knowledge exchanges that accompany these built in-depth competence and networks among this set of enthusiasts then fed into user intermediating (Hyysalo et al., 2013b, 2018). User innovations can be found from the take-off phase to the late acceleration phase.

The championing of ambitious projects, in community building and in the dissemination of information by users, happens from the exploration phase to the acceleration phase. Project championing (Klerx and Aarts, 2013) must have taken place in early pioneering projects that were novel and also demanded considerable effort from the adopters (Lauttamäki, 2018). In later phases, technology championing is seen in efforts to introduce heat pumps into new non-standard installations, in the considerable efforts by users to assess the yield and payback times of both ASHP and GSHP systems (in particular, their settings and geographic zones), and in running joint-purchase projects (Heiskanen et al., 2011; Hyysalo et al., 2013b, 2018; Hyysalo and Juntunen, 2018). Championing intermediation (Martiskainen

and Kivimaa, 2018) took place in the internet communities, where a group of roughly 500 people provided tens of thousands of responses to various queries from others. It is important to note that none of these efforts are necessarily advocating heat pumps but geared to serving oneself and helping others on the side.

Community creation and maintenance have been an important catalyst for other user activities. There is sporadic evidence of local communities playing a role in the exploration and start-up phases, while the internet communities played a substantial role during the acceleration phase. A key feature here has been the accumulation of a critical mass of community members and information that has accumulated in such a way that the internet communities have served the varying needs of prospective adopters and existing users. In the Finnish heat-pump transition there was the coincidence of the emergence of the first tens of thousands of users with the emergence of easy-to-set-up discussion platform technology (Hyysalo et al., 2018). The later diffusion of solar PV and solar heat in Finland showed that internet communities could play a role from the early take-off phase, but the critical mass has been slow to cumulate (Hyysalo et al., 2017; Hyysalo and Juntunen, 2018). Regarding locality-based communities, there have been few community energy initiatives or joint purchases that are significant for heat pumps; yet interactions in local communities where somebody has adopted a heat pump have been conducive for spurring further adoption among peers; for instance, within carbon-neutral municipalities (Heiskanen et al., 2017b).

Intermediation by peers comprises not only facilitation but also the configuration of equipment and brokering of connections (Stewart and Hyysalo, 2008). Intermediation has a dual form in the Finnish heat-pump transition: first, as local peer-to-peer encounters and, second, as an aggregated many-to-many phenomenon, amplified by internet communities (see Chapter 4). In local sites, intermediation takes place from at least the take-off phase onwards (Heiskanen et al., 2011, 2017b). The intermediation by users intensifies in the peer-to-peer communities, which facilitates learning about new technology and its use among peers. The accumulated display of exchanges about installations, use experiences, real-time monitoring, technology concerns in the cold-climate context, and DIY solutions also contributed to demand articulation and technical improvement (see Chapter 4). In internet communities, direct peer designing was rarer as the distances between users prevented peers visiting each other (cf. Meelen et al., 2019), but help with configuring equipment was abundant, as was help with the brokering of contacts.

Market creation activities are not unidirectional supply-led initiatives that spur demand—they form an interactive process in which adopters take part. One aspect of this is that adopters spur their peers on with buying decisions by providing examples and testimonials as to the worth of the goods. The other aspect is that in order to act in the market, potential adopters need to be able to make

sense of the qualities of products, compare them, and establish an understanding of what consequences different choices hold for them (Callon et al., 2002). Both these aspects of market creation were central to the intermediation that users provided and particularly in the internet communities (see Chapter 4). The internet discussion forums were particularly important for storing and updating the technology, product, and market information in the changing field during the acceleration phase. They also indirectly policed supply and retail actors through fostering brand- and make-specific discussions that highlighted problems, such as erroneous supplier claims or substandard installation services (Hyysalo et al., 2018).

Legitimacy building is a key process in how a new technology becomes intertwined in the fabric of society (M. Suchman, 1995; Janasik, 2011), and there is evidence of this happening in the acceleration phase of Finnish heat pumps. The early stages of a new technology are characterized by uncertainties, doubts, and counterclaims to its proponents' narratives (Phaffenberger, 1992). Such "technological drama" is the overtly politicized side of sociotechnical change, wherein citizens and citizen movements play an active role (Williams and Edge, 1996; Smith, 2012; Schot et al., 2016). Adopters can, however, also play a key role in the regularization of technology with less sound and fury. As presented in Chapter 4, the internet communities fostered and made visible a positive legitimating discourse about heat-pump technology. While forum discussions feature plenty of critiques, they also feature a conspicuous absence of wholesale doubts or dismissals of heat pumps, generic technology critique, or even the sustainability-related ideological discourse typical of grassroots innovation and critical niche communities (Smith et al., 2014). Such taken-for-grantedness may well be the most powerful aspect of technology-related discourse, and when it was displayed in over 300,000 messages that attracted over to hundred million reads, the effect was considerable.

To clarify the interrelations between the above-described user activities and their importance to understanding transitions, we proceed through two sequential diagrams. The first diagram (Figure 5.2) presents the actor-level interrelations between the activities of the users and how they link to niche, regime, and landscape actors. These relations can be observed from the take-off stage onwards in the Finnish heat-pump transition. Let us first clarify the basic interrelations. Adoption and a growing market foremost signal user activities to other niche actors and to users still aligned with the existing regime (the dots with horizontal lines in Figure 5.2). Among the adopters, some champion new types of projects as well as peer interactions in local and internet communities (the ascending line dots). Some adopters must make adaptations and adjustments (the descending line dots), and a small subset of these people proceed to DIY projects and further user innovations (the checkered dots) as well as to user intermediaries who help others (the dots with grid). The user innovators affect other users through three mechanisms: by adding to the solution variety available to adopters and adapters, by

Figure 5.2 The actor-level relationships of user activities in Finnish heat-pump transition.

signaling designs and design needs to resellers and manufacturers that serve the niche, and by providing technical and practical competence in intermediation in communities, allowing these to deepen into useful repositories of knowledge and encouragement (the dotted circles) that help mediate the other activities.

The actor-level depiction of user activities needs to be complemented by adding to the depiction activities that emerge and intensify when the adopter base grows and becomes connected through internet communities. These included a wide intermediation among peers that was not confined to just a few locations (the dashed-line circle), market creation (the dash two dot circle), and the creation of legitimacy through widely read regularizing discourse (the dash-dotted line circle). The intensification of these user activities affects the other niches, regimes, and landscapes to varying extents, but particularly the not-yet users who are still aligned with the regime but gradually rethinking their heating solutions.

Figure 5.3 aggregates the actor-level findings to an overall transition-level depiction for comparison to earlier schematics by Smith (2012) and Schot et al. (2016). The complex interrelations between user activities have been suppressed in favor of portraying the user activities in the course of the transitions, a common facet in transition models that seldom address the actor interrelations in detail.

Figure 5.3 User activities presented at the transition process level.

The key features in Figure 5.3 are the emphasis on the technology expanding into new adopter segments in the course of the transition, which is aided by user contributions to adaptation, innovation, championing, communities, legitimacy creation, intermediation, and market creation. The user activities have influences on and interactions with other actors in the expanding niche, with neighboring niches, and with regime actors.

Importantly, all the user activities depicted in Figure 5.3 have incidences across the transition and we refrain from making assumptions about the relative importance of different user contribution types in different phases. We place legitimacy building, market creation, and intermediation highest up on the list as they intensify the most in the Finnish heat-pump transition (dashed wider circles in Figure 5.3). This is because isolating the relative importance of different user contributions is not supported by our data and may in fact be methodologically impossible because of the different mechanisms of influence among tens of thousands, and later hundreds of thousands, of users. (See the chapter conclusions for an extended discussion on this point.) The mutual influences are better portrayed in an actor-level model.

5.4 Understanding transition as a series of configurational movements

To render transition studies more capable of addressing the specific phenomena of interest within the overall systems change, more fine-grained theoretical registers may be needed as already hinted by the difference between actor and transition level models of user activities 5.2 and 5.3. In this book such a register

is pursued through ecological views of sociotechnical relations, particularly the concepts of arena and ecology actors introduced in Chapter 2 that help trace local transition as a *series of configurational movements* (Hyysalo et al., 2019a). These movements amount to “key biographic moments” in the change process studied (as worded by Glaser et al., 2020). In these moments the relationally constituted character of a technology, its material make-up, underlying principles and theories, designed artifacts, and the practices of associated people are shifted. In previous BOAP studies, four typical moments and configurational movements can be discerned in the life-cycle of a technological artifact: constructing the problem, selecting and developing a solution candidate, deploying and using the technological assemblage, and reusing and translating the technology in other locations (see, e.g., Hyysalo et al., 2019; Glaser et al., 2020; Hyysalo and Usenyuk, 2015). For our interest here, however, the picture is somewhat more complex as socio-technical change in energy transition takes place at the scope of a technology field where several biographies interlink and produce aggregated effects (Pollock and Williams, 2008; Hyysalo, 2010). We thus need to traverse at once the key changes of particular sociotechnical assemblages, as well as the key changes at the aggregate level. Particularly in regard to this latter interest, the concepts of the ecology of actors and arenas become useful, and let us concretize these concepts with the example of early GSHP proliferation in Finland.

By *sociotechnical configuration* we mean the intertwinement or “assemblage” of those technical and social elements that produce outcomes in an identifiable setting (Latour, 1987, 2005). A simplified example of sociotechnical configuration in heat pumps is, for instance, a “horizontal GSHP system.” It is comprised of the following:

- a horizontal collector GSHP, the requisite plot of land, and land-moving equipment
- the design choices made by the equipment manufacturer and its component providers
- the sales arguments, pricing, delivery types, and resellers
- installation practices by installers and adopters
- the adopter practices in the running and maintenance of the GSHP unit and its collector field; the re-landscaping of the collector field
- the management of heat intake
- heating needs and other heating solutions by the adopter
- the management of winter ground frost by adopters.

This non-exhaustive list underscores that the “artifact” is never the center of attention nor the defining point of analysis as such, but always exists in a “contexted” way in particular settings where the artifacts are enacted and consequential, as Glaser et al. (2020) put it.

The elements of configuration, be they “technical” or “social” at a particular site of configuration, are bound to actors through the materials, designs, principles, theories, usage, and regulations that are enacted

(Hysalo, 2010) and may *imply* other actors and actor behaviors. For instance, a horizontal collector field for a GSHP implies an adopter who can lay hundreds of meters of coil in the close vicinity of his house without being disturbed by the effects on his house surroundings, including the prospect of potentially having to dig the ground up anew to mend problems that may occur with the coil.

But sociotechnical configurations around particular installations that are bound to and imply actors also point to a wider *ecology of actors* that bears an effect on the *technology type*—typically consisting of tens of competing makes and models—in a particular *arena* in which these actors have their dealings (that may involve several types of technologies at once) and through which the arena is defined among the different social worlds present in it through the involved actors (Strauss, 1978; Clarke and Star, 2003; see Chapter 2). The sociotechnical configurations related to an ecology of actors and to an arena are typically multiple, and each implies a subsection of the actors in the area, while their effects typically reach further in the arena. Once the technology type and markets mature, the result is a relatively stable industrial field. But because the field organization is the long-term result of sociotechnical change rather than its pre-condition, the ecology of actors and arena concepts are more apt for discussing it than using the term “industrial field” until there is a field that has matured into existence.

By *configurational movements* we mean significant shifts in the configuration, typically comprised of new actors, materials, practices, regulations, or competencies becoming intertwined in (or replacing) the previous relations. A common way this happens is that the site and situation for the configuration change so that they become tied to a new actors that were only implied earlier (and conversely, previous ties may loosen up). To give a simplified example of GSHP systems at the scale of a *technology type*: Once vertical borehole design and installation solutions were developed, they not only expanded the user base to new types of peoples, houses, and allotments, they also tied the borehole drilling companies into the ecology of actors (largely replacing land-moving operations) and further changed the material make-up of GSHP systems, their installation competencies, and their principles as it became paramount to be able to estimate how deep a well would provide the needed heat yield in different types of ground (Lauttamäki, 2018). At the scale of a *technology type*, the above movement forms a part of a configurational movement wherein the heat-pump field became reorganized with new types of heat-pump products, resale operations, and the establishment of industry associations for heat pumps and drilling operations (see the below Movement Number 3).

With these clarifications in place, we can recount the Finnish heat-pump transition at the level of the emerging technological field through nine major configurational movements. The first key arenas and configurations for all S-RET systems resided outside Finland in the 1970s, when the basic heat-pump, solar PV, solar collector, pellet burner, and micro-wind designs first

gained commercial introductions and early markets. The ecologies of actors in these arenas typically featured experimentation by researchers, (typically modest) commercial producers, and users alike (see, e.g., Smith, 2014; Heiskanen et al., 2014; Lauttamäki, 2018; Nielsen, 2016).

With Finnish heat pumps, these international arenas led to the rise of a local heat-pump arena (second configurational Movement) in the early 1980s with 12,000 adoptions that emerged in response to rising oil prices and company offerings of the early GSHP and water source heat-pump technology. As noted the ecology of actors was comprised of small resellers and producers (or the small sub-units of larger companies) and early adopters who proceeded to purchase and then run (and struggle with) their installed systems. As described above, this configuration fell apart once fossil energy prices decreased and new purchases stalled, forcing vendors out of the market, leaving users to grapple with their systems as best as they could, and leaving in place little more than general skepticism toward heat pumps.

The next Finnish arena for heat pumps, emerging in the late 1990s, was equally pre-configured through the international arenas of both production and use that had made heat-pump technologies more developed: ASHPs for cooling purposes and GSHPs in heating through vertical borehole technology (the third configurational movement). This time the local arena had a more organized ecology of actors that featured not only resellers, installers, and small manufacturers but also featured two industry associations that salvaged the hard-won insights from the first configuration and its failure. By 2005, 60,000 installations had accrued, yet the heat pumps in Finland proliferated against the grain of country specifics, market conditions, and institutions (Heiskanen et al., 2017a; Lauttamäki, 2018; Lauttamäki and Hyysalo, 2019). This Finnish configuration (the fourth configurational movement) was thus, from the user side, still centered around *early adoption and the achievement of routine use*, shrouded by uncertainties as to the technology yield, savings, pay-back times, and scaling, as well as to vendor and installer trustworthiness. The adoptions required competencies in understanding what the new technology is and how it works, its potential suitability, possible permit issues, cost-benefit calculations, comparisons between suited makes and models, installation types, and the possibilities and requirements for routines, use, maintenance, and monitoring.

Thus the fifth configurational movement in the same arena and ecology of actors: sales and adoption were not only important, many users undertook *adaptation, championing* when they faced the need to alter the equipment or their social and technical contexts (physical houses, daily practices), and also their networks in regard to finding professionals to do non-standard installations and clarifying permits etc. This configurational movement among users was often invisible to other actors in the ecology. Here new competencies and materialities were highlighted as the technology and its context were no longer just bought and operated but tinkered with and adjusted in order that they work in a non-standard manner.

The sixth configurational movement emerged with small subsets of people further improving their equipment through DIY projects and *user innovations*. This called for radically deeper engagement with the technology and the competencies to deal with it, including new kinds of peer exchanges. The adaptation and innovation activities changed heat pumps from a novel and difficult-to-understand black-boxed technology to a malleable good that could be adjusted and improved. These activities also affect other users through adding to the solution variety available to other adapters as well as signaling further design needs to resellers and manufacturers. As noted, people pursuing DIY and user innovation turn out to provide deep assistance in user communities.

The seventh configurational movement took place through new market and intermediary actors entering the ecology of actors, namely large hardware retailers and the build-up of *internet-based user communities*. The initially modest peer-to-peer knowledge-sharing platforms rapidly grew into popular, diverse, and deep repositories of knowledge in just five or so years, contributing to the intermediation, market creation, and legitimacy of the new technology and affecting the not-yet users aligned with the regime but gradually rethinking their heating solutions.

The eighth configurational movement was the *mass adoption* associated with the maturation of both the Finnish residential heat-pump arena and the stabilization of its ecology of actors, leading to increasing normalcy of residential heat pumps in resales, regulations, and public and professional media, as well as in adopter choices. The second decade of heat-pump proliferation after the restart (2006–2015) featured over a tenfold growth, which has continued since. This growth was not automatic, as it may appear to be from just examining the numbers, nor a simple result of an effective industry association (Berninger et al., 2017): it was paired with and made possible by a gradually structured market, knowledge institutions, and technology characteristics to which all of the seven earlier configurational movements contributed. The technical configuration gained further support from neighboring technologies, from generally improved insulation levels, and from the increasing adoption of underfloor heating that supported GSHPs' and ASHPs' capacity to act in conjunction with existing heating technologies and other S-RETs in residential houses.

The ninth and ongoing configurational movement concerns the present breakthrough of industrial-scale heat pumps in the large building market and as part of district heating networks. Owing to advances in large-scale heat-pump systems, the growth of some Finnish suppliers serving the residential housing GSHPs, and the availability of ground heat-potential modeling, these companies could start making competitive bids for heating larger installations that had previously been won by bespoke fossil-heated power generation or district heating networks.

This series of configurational movements provides a lens through which to view the specifics of how a new technology becomes socially and materially shaped in the course of sociotechnical change—it reconnects the user activities (Figure 5.2) into the dynamics of sociotechnical change in a manner

that helps to focus on the situations and dynamics that matter the most. All the nine sociotechnical configurations feature some interactive dynamics between the *supply side* and *demand side* and intermediation processes, but Configurational Movements 3 and 8 are owed mostly to the actions of the supply side and Configurational Movements 5, 6, and 7 to actions taken on the demand side, in such a way that Configurational Movements 3, 5, and 7 imply a field-organizing intermediating move from the position of users or suppliers.

Innovation and sociotechnical change processes are known to feature considerable contingencies and idiosyncrasy among repeating patterns (Russell and Williams, 2002). Abstracting from the above analysis, we suggest a tentative set of abstracted configurational movements that are likely to occur in the course of a technology type becoming successful in a follower country of a transition technology (see Figure 5.4):

- 1) The search for principles of basic solutions and their design take place elsewhere (supply, demand)
- 2) Initial domestic introduction and adoption form a nascent ecology of actors (supply, demand)
- 3) Adaptation, championing, and user innovation take place to better suit the technology to the consumer specificities in the country (demand)
- 4) The build-up of sufficient intermediation takes place and lays ground for the emergence well-working domestic market (supply, demand, intermediaries)
- 5) Further technology and global market development feed into the development of the domestic market (supply, demand)

Figure 5.4 A configurational model of technology proliferation in follower contexts.

- 6) The emergence of mass-market conditions and the maturation of the industrial field (supply, intermediaries)
- 7) Interplay with adjoining technologies, the emergence of new sociotechnical configurations, and feeding back to the global technology field (supply, demand, intermediaries).

5.5 Chapter conclusions: the yield to and from transitions research

Users' engagement in the shaping of new technology presents a well-established research area for several disciplines. Sustainability transitions research stands in a dual position vis-à-vis this earlier work. On the one hand, it presents a perspective that may have the potential to integrate and cross-examine a range of the citizen and user contributions that take place in the course of long-term sociotechnical change—a capability of obvious importance in the face of the compartmentalization of user-related research in innovation, diffusion, consumption, design, informatics, social movement, and S&TS (Hyysalo et al., 2016a; Kohtala et al., 2020). On the other hand, the research on user and civil-society influence on sustainability transitions has only recently begun to move beyond the more narrow framings of these earlier lines of study, leaving a research gap between overall appraisals and the detailed studies on users within sustainability transitions (Heiskanen et al., 2014; Schot et al., 2016; Kanger and Schot, 2016). Our investigation into user activities related to Finnish heat pumps combines historical and ethnographic studies and integrates multiple topical sub-studies, and it is also the first empirical analysis that is detailed enough to be likely to highlight a considerable part of the *invisible work carried out by users*, as well as to cover the majority of the transition from the beginning of the transition to the late acceleration phase.

The findings support examining the import of the manifold contributions that users make throughout the transition process without findings becoming siloed into different disciplinary discourses (Smith, 2012; Schot et al., 2016). Described at the actor level (condensed in Figure 5.2), our study reveals a richer set of users' active engagements and provides a more nuanced understanding of their interlinkages in the process of sociotechnical change than has been provided before.

The protracted spread of solar power, wind power, and heat pumps, and the use of micro-scale biomass despite price parity have made it clear that there is more to understand about adoption than economic and institutional development. The transition solutions move from ideally suited sites and locations to less ideal ones (Meelen, 2019; DeWald and Truffer, 2012), from early consumer segments to followers, and from early institutional contexts to those pertaining to mass adoption (Ornetzeder and Rochrachner, 2013; Nielsen, 2016).

In our analysis, *adoption* and the consequently growing market are the prime mechanisms that signal user activities to other niche actors, as well as to the regime, landscape, and potential users still aligned with the existing regime.

Adoption is, however, importantly facilitated by a range of other engagements with the niche technology. *Adaptation* and *championing* ensue when subsets of users face the need to alter the equipment or their social and technical contexts (physical houses, daily practices), and also their networks, for instance, in finding professionals to do non-standard installations and clarifying permit issues etc. Small subsets of people further turn to improving equipment (or saving costs) through DIY projects and *user innovations*. These activities affect other users through adding to the solution variety available to adapters, signaling further design needs to resellers and manufacturers, and by providing deep-level competence for *intermediation* in *user communities*, allowing these to build up into major repositories of knowledge and encouragement. Our analysis further suggests that user communities are conducive to playing a role in *market creation*, may provide wide and easily accessible intermediation among peers, and contribute to *building legitimacy* for novel technology. This intensification pattern is clear in Finnish heat pumps and has significantly affected not-yet users aligned with the regime but gradually rethinking their heating solutions. A transition-length depiction (Figure 5.3) underscores the continuation of adoption across different adopter segments and interactional effects between user contributions and other niche actors but downplays the user activity interrelations for clarity.

In articulating the actor- and transition-level contributions by users and their interrelations, our analysis stands in some critical contrast to earlier studies and theoretical proposals on users in transitions. The first of these concerns the assumedly politicized nature of transition. The transition in residential heating in Nordic countries, in which heat pumps have been a key technology, has been characterized as a “silent revolution” (Johansson, 2017), and as a corollary to this its user-side features remarkably less politicized civil-society activities than transition models and previous studies of citizen engagement have put forward (Smith, 2012; Ornetzeder and Rohrer, 2013; Schot et al., 2016). Similarly to solar PV, solar heat and biomass use, heat pumps in detached houses can mostly be installed through direct substitution without wide system changes, yet still *instill* wide systems change, as is evident in the defossilization of Finnish space heating in detached housing and the associated change in the actor groups involved in the field.

The second contrast concerns distinct-phased contributions by users. Our data supports the idea of the intensification of some user influences through the emergence of much-read internet communities during the acceleration stage but not a stylized grand transition narrative where certain user functions or roles would be dominant in certain phases toward not-yet users aligned with the regime or toward other regime and landscape actors.

The extended time frame of study also questions some assumptions made in other fields studying users. Even though user innovation has elsewhere been found to be most concentrated in the early development phases of new technology types (von Hippel, 2005; Franke et al., 2006), in Finnish heat pumps it continues long into the acceleration phase (Hyysalo et al., 2013a,

2017)—this may well have happened in other small-scale energy technologies yet escaped attention as only the emblematic early stages have hitherto been systematically studied (Ortnetzeder and Rohrer, 2006, 2013; Nielsen, 2016).

Third, our study underscores issues regarding the terminology used in characterizing user activities and their emergent effects. We find it is sensible to talk about *champions* and *legitimacy building* rather than *advocates* and *legitimizers* (Schot et al., 2016; Kanger and Schot, 2016). Championing is evident in our data, but active and important advocacy is less so, beyond isolated instances. Similarly, the hundreds of thousands of moderated posts and 200 million reads in internet communities aggregate into a legitimating discourse, while few discussants actively pursue legitimation. The terminology used is consequential regarding what demand-side dynamics and empirical phenomena researchers pay attention to, whether one underscores individuals as role holders or whether one directs attention to their activities and possible aggregated effects – for instance it would be illusory to incentivize people into better filling an assumed role, when the “role” turns out to be an aggregate side-effect of the factual activities they pursue.

Finally, our analysis suggests that there is a need for recalibrating transition research for the acceleration phase and invisible work by actors. Most of the evidence for transitions has been amassed from globally studying new niches in the settings where they have first occurred. *These globally early settings*, as important as they are for creating the alternatives that may then spread to other contexts, *may in fact be rather poor model organisms for how the majority of the localized transitions* are likely to play out after take-off. The late-mover settings interface with the alternative solutions that are already in a more developed phase technically regarding commercialization, distribution, and usage patterns. At the same time, the late-mover settings are likely to feature characteristics that differ from the early development contexts and which may have barred the early proliferation in the first place. These may relate to geographical conditions, competing technologies, the institutional environment, market conditions, or issues of wealth and inequality (and so forth). Finnish heat pumps are a good example of a transition process that (re)started after a death spiral at the point when both GSHPs and ASHPs had already passed their early development phases in other countries. This contributed to their fast proliferation in Finland, but this has not meant a smooth or inevitable diffusion as we detail above. In comparative terms, the relative global position is likely to result in somewhat different patterns, for instance, in the speed of the acceleration phase, the nature of institutional development, and in public discourse, as well as in the user activities in the transition. Tracing the *series of configurational movements* in heat-pump transition identifies which concrete dynamics to look for and provides points for advancing transitions on the ground. A minimal set of seven abstracted configurational movements in a follower country point to the likely dynamics and shifting locus of action in the shaping of sociotechnical change (cf. Williams and Edge, 1996).

5.5.1 Methodological considerations: Recalibrating transitions research

While some transition scholars slant S&TS as being too inductive to yield generalizable models, the BOAP investigation not only suggests that this depends on how S&TS is carried out but also highlights the practical and principled difficulties in “testing” broad transition models. Because of the long temporal span and wide scope of the empirical domains involved, mustering direct reliable evidence in support of or against the general transition models may prove elusive. This is particularly so as they feature such key explanatory constructs as “rules,” “learning,” and “interactions” and actor groups like users and intermediaries. These are phenomena and actors on which empirical data is seldom systematically recorded and regarding which also indirect evidence such as time series kept by statistical bureaus or industry associations tends to be lacking.²

User contributions to transitions are a good example of the methodological issues involved because of the three senses of the invisibility of their contributions and the sheer numbers of users as the transition progresses, and allows us to discuss which of the key constructs of Smith (2012) and Schot et al. (2016) find support, which do not, and which are most likely impossible to verify.

First, there are general-level assertions in both the models of Smith and Schot et al. regarding users and consumers. These are assertions that transition progresses from early, underdeveloped technology, market, and social characteristics where adoption is a pioneering act to a point where it has become more natural and legitimate for consumers to make choices favoring the new regime; that users and civil-society actors play a significant role throughout the transition process; and that they do so in several ways beyond just adoption and financing. All these three assertions find ample support from the Finnish heat-pump transition and our investigation clarifies further the mechanisms through which the various user contributions have taken place across one transition. So, our study could be taken as largely confirmatory of these general-level assertions. This said, these assertions reside at such a high level of abstraction that their value to understanding transition and users remains limited—users and civil society matter across the transition, and then what?

Regarding the more specific assertions regarding what, how, and when users and civil-society actors contribute, we should first acknowledge that Smith rather provides an illustration of how various civil-society formations may have an effect on transition processes and this we believe to be a sound way to link piecemeal research evidence to high-level transition models. In contrast, Kanger and Schot (2016) have proceeded to use the model of Schot et al. (2016) *as a theory to be tested* and it thus makes sense to discuss their constructs and their verifiability in more depth.

As noted in the introduction to this chapter, their core construct is the relative importance of five user contribution types in different transition phases. In Finnish heat pumps, all these user activity types can be found in all transition phases. But it remains unclear why just these five types would be important as the Finnish heat pumps alone surface eight salient user activity types that contribute

to transition, and there are several more, such as peer finance, that are known to have featured in other transition process and are distinct from e.g. “user-consumers.” Smith’s recounting of the wide range of possible civil-society roles gives further impetus for asserting that it is simply *too early to synthesize and close the list of relevant user roles, let alone user types, in transitions and move to testing a small set of them.*

The construct of the phased relative importance of different user contributions may, in turn, be unverifiable. Evidence of some incidence of all eight types can be found in all phases in our study on heat pumps. But being able to show incidence is not evidence for the distinct phasing of importance. There would need to be a schema for *empirically evaluating* relative importance over varying incidences across the very different influencing mechanisms of innovation, adoption, consumption, intermediation, and legitimation. This is likely to remain impossible to do in a sound way, leaving the phased importance empirically unverifiable and thus very ill-fitting to the espoused “theory-testing” view of whole transition models. Theories meant to be tested must be testable, or else they are just rhetoric that rides under the guise of academic rigor.³

Taking a step back from models on users in transition draws our attention to the status of high abstraction “overall story” transition models. To cover the considerable ground that in fact may remain between the overall story and the particular empirics in different countries, technologies, phases, and settings require mid-range registers and investigation programs. These need to be, on the one hand, detailed and sensitive enough to the studied phenomena and, for instance, refrain from imposing unverifiable constructs derived from high-level models (and need to rather question the adequacy such parts of the models), and on the other hand, they need to bridge sufficient amounts of empirical sites and times to arrive at grounded abstraction. This is the mid-range methodology road that the BOAP approach illustrates as being one possible avenue for future transitions research.

Notes

- 1 Statistics Finland, 2019; personal communication with expert Hanna-Liisa Kangas November 23, 2019, on how the “others” category in Finnish building statistics is divided in this regard.
- 2 Scott-Kemmis and Bell, 2010; Miettinen, 2003. This is particularly so as transitions models imply these processes are spread among a great diversity of actor groups and thus also dispersed data-wise.
- 3 In addition constructs such as “user-legitimators” who approve the new technology even if they do not adopt it (e.g., dwellers in district-heated blocks of flats that cannot switch to heat pumps but endorse them) can potentially cover everybody in the country. The question thus arises, how could one assess how the general population shifts its perception of an emerging technology? The methodological imagination coming closest to this would be a representative survey sent to a sample of citizens at set intervals, such as every three years, akin to political party voting polls, from the beginning of a transition to its end. The survey would, however, be seriously complicated by the fact that many of the

sampled people would not be familiar with the new technology in the early transition phases, and hence the 2000 or so different people required to be contacted in Finland would need to be gauged not by simple mail or phone protocol but by qualitative interviewing supported by technology explanation. While this is a research design that is very unlikely to be ever be pursued, even such an exhaustive research design would still arrive at changes in the incidence of just one user role and thus still be unable to address the construct of relative importance.