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Research article

User innovation, niche construction and regime destabilization in heat pump transitions

Mari Martiskainen[a], Johan Schot[b,*], Benjamin K. Sovacool[a,c]

[a] *Science Policy Research Unit (SPRU), University of Sussex Business School, University of Sussex, United Kingdom*
[b] *Utrecht Centre for Global Challenges, Department of History and Art History, Utrecht University, The Netherlands*
[c] *Center for Energy Technologies, Department of Business Development and Technology, Aarhus University, Denmark*

A R T I C L E I N F O

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A B S T R A C T

Domestic heating systems require a rapid shift to low-carbon options to meet global climate targets. We analyse a heat pump transition in two contrasting case studies: Finland and the United Kingdom, utilizing original data from interviews, document analysis, and archival online data. Finland has an almost completed transition, while the United Kingdom can be considered a stalled one. Building on previous research that has highlighted the importance of context, policy and users in transitions, we explore various user roles within low-carbon transitions, and how they shape processes of niche construction and regime destabilisation. Our findings show that the role of users is one key explanatory element of the different heat pump transitions. We also find that specific characteristics of a transition context can influence the types of users that emerge. We conclude that instead of just providing incentives, policy should also aim to mobilise users.

1. Introduction

There is widespread agreement that decarbonisation of the energy system is required to limit climate change inducing greenhouse gas (GHG) emissions. Limiting global warming to 1.5 °C will require reaching 80 % of zero-emission energy by 2030 and 100 % by 2050. Cumulative GHG emissions must be reduced at least by a further 470 gigatons (Gt) by 2050 compared to business as usual (IRENA, 2019). Such climate policy imperatives have sparked a veritable shift to low-carbon innovations across a variety of domains, with heating especially given a focus as a key, yet also a challenging sector, to be decarbonised.

While it is clear that a low-carbon energy transition requires a multitude of technologies and policies, in this study we focus on heat pumps, which have been shown to be a critical low-carbon option for meeting domestic heating demand, potentially leading the way towards a broader transition. The International Renewable Energy Agency (IRENA) (2019) projects that to meet climate objectives, the number of heat pumps in households needs to jump from 20 million in 2015 to 253 million by 2050, more than a tenfold increase. This is not simply a process of heat pump adoption, but in fact a transition to a new indoor domestic regime that requires many other regulatory, institutional, market, industry, and cultural changes in addition to the technological ones.

In this article we explore one crucial factor for a heat pump transition to happen and even to accelerate: the role of users. While transitions are very complex processes and magic bullets do not exist, we may expect the role of users to be a pivotal component. Previous research on product innovations, for example, has shown that user involvement is crucial—users are a source of product

* Corresponding author at: Utrecht Centre for Global Challenges, Department of History and Art History, Utrecht University, Janskerkhof 2-3A, 3512 BK Utrecht, The Netherlands.
E-mail address: j.w.schot@uu.nl (J. Schot).

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innovation, modification and redesign, and without them product innovation has a much larger chance to fail (Von Hippel, 1986, 2005; Bogers et al., 2010; Hyysalo et al., 2017). Thus not surprisingly, users are getting more attention in sustainability transitions research. While here the focus is less on product innovation and more on socio-technical systems, various studies have established that users are playing an important innovative role (Truffer, 2003; Ornetzeder and Rohracher, 2006; Shove and Walker, 2010; Heiskanen et al., 2011; McMeekin and Southerton, 2012; Schot et al., 2016; Meelen, 2018).

Previous transitions research on users suggests that a variety of user types are involved throughout the entire transition process in its different phases. Users are not only essential during the start-up phase of transitions when they co-design niches, but also during the stabilization phase when they domesticate new regimes and systems, and the acceleration phase when new systems become embedded in their environment and shape future selection-environments (Schot et al., 2016; Meelen et al., 2019). More research is necessary, however, on the salience of various user roles and how they influence the nature and speed of various transition trajectories. An important feature of transition research is the emphasis on the need for the destabilisation of existing rules and routines (i.e. regime destabilisation) related to prevailing unsustainable systems which sustain problems such as the climate crisis. This leads to our main research question whether and how users are involved not only in the construction of niches and new systems, but also in the process of regime destabilisation (Grin et al., 2010; Markard et al., 2012; Geels et al., 2017). We decomposed this question into three sub-questions which we utilized to collect our original data and to structure the analysis of our findings:

1 Which user types are most salient, and at which times, in a heat pump transition?
2 How did these user types contribute to both niche construction and regime destabilisation?
3 To what extent is the involvement of various user types an explanation for divergent heat pump adoption?

We answer these questions through a case study approach using mixed methods that compares a heat pump transition in two contrasting subcases: one where a successful transition has taken place (Finland) and another where a transition has had difficulty getting off the ground (UK). In Finland, a country of just over 3 million households, an estimated 1,030,000 heat pumps have been sold since 2000 (SULPU, 2020a; SULPU, 2020b). Household heating systems in Finland have thus witnessed a move away from fossil fuels (they do use electricity, but 46.2 % of electricity generation in Finland comes from renewables (Statistics Finland, 2019)). In the UK, a very slow and low adoption of heat pumps has taken place. The majority of the UK's 27.6 million households still rely on fossil fuels (gas) for their heating and only an estimated 160,000–200,000[1] heat pumps have been installed in the country. Each year, Lipson (2018) reports that the gas boiler market sells 1.5 million units but the heat pump market is constrained at only 20,000 annual installations.

Our article is organised as follows: Section 2 contains a background to heat pump research in Finland and the UK, including also the basics of the technology. Section 3 outlines our theoretical approach on the role of users in energy transitions. Section 4 explains our research design and case study methodology. Section 5 presents a brief history of the heat pump transition in both countries. Section 6 discusses our three subquestions related to users, niche construction and regime destabilisation, and provides an answer to our main research question. Section 7 concludes discussing a few policy implications.

2. Literature review: Background to heat pump research in Finland and the UK

In this section we review previous literature that has focused specifically on heat pump research in Finland and the UK. However, we first provide a brief introduction to the basics of heat pump technology.

2.1. Introduction to heat pump technology

Heat pumps are diverse, using renewable energy from air, water, ground or exhaust air from buildings to provide heating and cooling (Nowak, 2018). Heat pumps can be used for different purposes including providing heating and cooling for buildings, generating electricity and providing hot water (Soltani et al., 2019). The basic operation of a heat pump is based on 5 components: an evaporator (a "liquid-to-gas" heat exchanger), a compressor, a condenser (a "gas-to-liquid" heat exchanger), an expansion valve and a transfer fluid (refrigerant) (Nowak, 2018). For those seeking more technical details, operational and performance dynamics are explained in Nowak (2018: 18–19).

Heat pumps are most commonly divided into three board categories. *Air source heat pumps* (ASHP) extract heat from outside air and circulate it to heat space only (Air-to-air Heat Pump AAHP) or space and water (Air-to-water Heat Pump AWHP). One type of ASHPs is an Exhaust Air Heat Pump (ExHP) which extract heat from the exhaust air of a building, and transfer it to the heat the building air, water or water-based heating systems. Ground source heat pumps (GSHP) extract heat from the ground, collecting heat via a closed loop either via vertical boreholes or horizontal pipes buried under ground. Water source heat pumps (WSHP) use the same principle as GSHPs, but they use water directly in an open loop, and they can be connected to the sea, lakes, rivers, aquifers, and/or wastewater, industrial cooling water or district heating systems.

Heat pumps are usually powered by electricity or thermal energy – the ratio between the share of driving energy and renewable excess energy is the coefficient of performance (COP) of the heat pump (Nowak, 2018). For example, many condensing gas boilers

[1] The number of heat pumps is based on estimates provided by the UK experts interviewed for this study. At the time of the interviews, there were no official statistics available on the number of installed heat pumps in the UK.

operate at 92–95 % efficiency (older models are less efficient having more wasted energy input) (e.g. IEA, 2020), whereas heat pumps can have 350 % efficiency in comparison. On heat pump heating mode, one unit of driving energy input is estimated to usually generate 3–5 units of heating output (Nowak, 2018). The International Energy Agency (IEA) has stated that even though only 5% of global building heating demand was supplied by heat pumps in 2020, their potential is large. IEA thus estimates that electric heat pumps could meet more than 90 % of global space and water heating demand, and do it with much lower carbon emissions than condensing gas boilers (IEA, 2020).

2.2. Previous research on heat pumps in Finland and the UK

Our research builds specifically on previous studies on heat pumps in Finland and the UK. We focus on those studies that have also explored the role of users, and address emerging gaps in knowledge.

As a starting point, and most relevant for our study, Hannon (2015) examined heat pumps in both Finland and the UK. His article mainly provided lessons from Finland for the UK, since heat pump penetration in Finland at the time was comparable to what was needed in the UK in order to meet committed reductions in GHG emissions. Hannon (2015) did not give much attention to users in his study, but instead outlined how UK policies could address structural differences between the two countries in terms of heat pump deployment. While both countries have liberal, competition-based, energy markets and legally binding commitments to decarbonize, the UK has a warmer climate; an older housing stock, which can make heat pumps less efficient; and a more extensive gas infrastructure serving 84 % of the homes (in Finland this is less than 1%, but the country was relying on more expensive electricity and oil options). Yet because of the similarities, Hannon (2015) concluded that the UK could issue new regulation for new and existing building stock, and bring the costs of heat pumps down through subsidies and tax incentives. Users, nevertheless, were hidden and assumed to be passive in this analysis, largely seen as being driven by regulation and costs.

Gross and Hanna (2019) compared household heating systems in the UK (gas) and Sweden (district heating and heat pumps). They do refer to users, but only in their capacity as (passive) consumers. They showed that in the UK, gas became the preferred and dominant household heating option in the 1970s, resulting in very high customer satisfaction: gas boilers are affordable, provide a high level of comfort, and are convenient and familiar to both customers and installers (i.e. they are easy to maintain and replace). The authors concluded that the current undesirability and unattractiveness of heat pumps in the UK is a logical consequence of past choices and policies, and thus can be undone by new choices though path-dependencies need to be taken into account. Majuri (2016) examined the success of Finnish ground source heat pumps (GSHP), also focusing on policy. She argued that while policy was important, a focus on the quality of installers reducing uncertainty for users was also needed. This relates to the basic argument of all these authors, that the aim of policy-making should be consumer comfort, making it easy for consumers to adopt heat pumps. Sovacool and Martiskainen (2020) examined four “rapid and deep” household heating transitions in Finland (heat pumps), China (solar thermal), Denmark (district heat), and the UK (gas boilers), but utilized the lens of polycentrism and governance to analyse their results, of which users play a very small role.

Heiskanen et al. (2014a,b) and Hyysalo et al. (2013a,b, 2017, 2018) focused on household heating and the introduction of heat pumps in Finland, though not reducing their success to policy or structural contextual factors. Instead they consider the active role of users in depth. They draw amongst others on the innofusion concept (Pollock and Williams, 2008), which sees innovation involving iterative loops between design and use. They conclude that users are a major contributing factor to the success and failure of heat pumps (and other small-scale household level renewable energy technologies), showing many examples of active users who have been involved in the introduction process of heat pumps (Heiskanen et al., 2014a,b). For example, users have created internet fora to discuss heat pump problems and possible solutions (Hyysalo et al., 2013a,b, 2017, 2018). They also found more than a hundred modifications by users. Users did not have an easy ride, but had to perform work to develop the adoption process. This body of research also identified a range of users: innovative lead users who engage in product development; local experts who do not tinker themselves but actively monitor their systems and demand specific changes; competent users who seek advice and educate themselves and hapless users who integrated heat pumps into their lives and may notice issues and problems that need to be solved. The upshot of the argument of these papers is that a heterogeneity of users exists, and this is an important source for transitions to happen. Users are an independent force, who co-design new systems, teach each other, lobby for policies, generate commitment amongst users and create markets (or niches in transition language). In fact, Heiskanen et al. (2014a,b) and Hyysalo et al. (2013a,b, 2017, 2018) seem to argue that without user involvement the transition would not have happened in Finland.

At a later work, Lauttamäki and Hyysalo (2019) examined the Finnish GSHP transition through the lense of the multi-level perspective (Geels and Schot, 2007). They found that GSHPs initially gained foothold in 1970s due to landscape pressures and suitable structural issues (oil-heated houses were relatively easy to convert to GSHPs at a time of oil price shocks). While there was a dip in the GSHP sector in 1980s, from 2000s onwards a combination of policy support, domestic manufacturing base, media visibility and lobbying aided the sector. They also refer to Hyysalo et al.’s (2018) previous work on Internet discussion forums providing a space for peer-to-peer sharing of user experience.

This begs the question about the role of users more specifically in the UK. A small number of studies have examined user acceptability (Liu et al., 2014), perceptions (Owen et al. (2013) and experiences (Caird et al., 2008, 2012; Lowe et al., 2017; Moore et al., 2015) of heat pumps. They conclude that user awareness of heat pumps is very low, which may perhaps also explain the interpretations of Hannon (2015) and Gross and Hanna (2019) of users as rather passive in the UK’s heating regime.

While each of these studies have value, none have actively compared in a systematic way the role of users between a successful transition (e.g. Finland) and an unsuccessful one (e.g. UK) for *heat pumps*. In our empirical study we examine the role of users both in the UK and Finland, armed with a number of specific propositions embedded in a theoretical framing about the role of users in transitions processes, as well as in system innovation.

3. Theoretical approach: the role of users in system innovation and transitions

3.1. System innovation and niche construction

System innovation is one core focus of the transitions literature (Grin et al., 2010; Markard et al., 2012; Geels et al., 2017). Systems consist of an aligned configuration of technologies, and infrastructures; regulations and governance structures; industry strategies and structures; market structures and user preferences, as well as cultural symbols and perceptions. These system elements are expressions of underlying shared, and relatively stable, set of rules or routines called a socio-technical regime which guides the behaviour of regime-actors. A transition thus not only requires a shift of system elements but also of these underlying routines, and hence transitions shift the directionality of innovation. Transitions hence concern the development of a new paradigm or regime that is more focused on solving sustainability challenges that cannot be solved within the dominant regime they substitute.

Sustainability challenges are usually addressed by new innovations that develop in niches. Historical literature on niche construction has well-established three main sub-processes that support the development and diffusion of niches: the development of expectations, the role of networking, and the importance of shared learning (Kemp et al., 1998). In later work, Smith and Raven (2012) dubbed these three sub-processes as niche nurturing and developed a framework which included also niche shielding and niche empowerment. Shielding refers to processes that hold at bay selection pressures. Smith and Raven (2012) make a distinction between active shielding (which means that niches emerge because of policy measures) and passive shielding (which means that a market niche already exist because a specific group of users willing to experiment exists). Niche empowerment refers to the process in which the technology becomes competitive and thus begins to threaten the regime. It may become competitive without changing the selection environment (and thus the regime; this is the fit-and-conform pattern) or it may transform the selection environment building a new regime (this is the stretch-and-transform pattern).

Geels and Schot (2007) identify four different transition pathways that have relevance also to how niches can develop and change regimes. These may also be relevant for exploring user roles, since depending on the pathway their role may vary. The four types are: a 'transformation' pathway in which moderate landscape pressure leads to regime actors developing innovation activities but

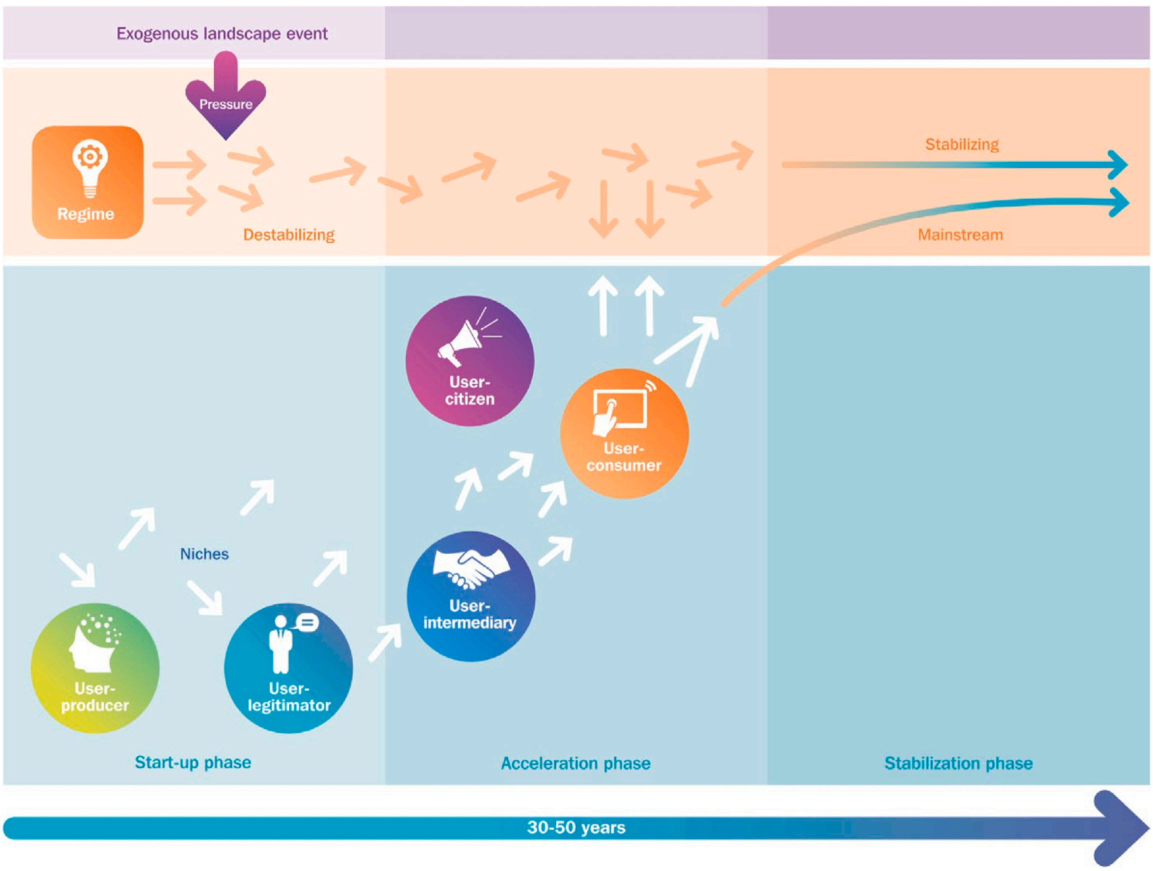

Fig. 1. User roles in different transition phases.
Source: Kanger and Schot (2016, p.610).

niche-innovations remain underdeveloped. A 'de-alignment and re-alignment' pathway includes a sudden landscape change that increases regime problems, leading to regime de-alignment and erosion, and provide a stimulus for niche innovations. A 'technological substitution' pathway sees the development of niche innovations that break through, replacing the existing regime. Lastly, via a 'reconfiguration pathway' niche innovations are adopted in the regime initially to solve local problems, but later leading to further regime change.

The transition literature has already shown that users can have a role in both niche development, as well as themselves be key in changing routines or rules expressed in the emergence of new innovations. Several studies have pointed for example at the important contributions that grassroots innovators have made in the development of niche innovations and starting up sustainability transitions (Seyfang and Smith, 2007; Hargreaves et al., 2013; Smith et al., 2016; Seyfang et al., 2014). While grassroots innovators construct niches for alternatives to flourish, they may not be necessarily interested in expanding these niches, and if they are, they often face a large number of challenges for niche expansion. New types of users may thus have to enter to take up this role, as has been shown in the case of car-sharing for example (Truffer, 2003).

A range of studies have shown that users can play a variety of roles for all niche construction processes: shielding, nurturing (including learning, networking and visioning) and empowering the niches in relation to the dominant system and regime (Ornetzeder and Rohracher, 2006; Dewald and Truffer, 2012; Schot et al., 2016; Smith and Raven, 2012; Randelli and Rocchi, 2017; Meelen et al., 2019; Meelen, 2018). Niche construction alone, however, is not sufficient for a transition to happen, but a transition also needs the destabilisation of dominant regimes. This leads to a little addressed question on the role of users in this destabilisation process. The role of users in this process has not yet received sufficient attention except perhaps energy cooperative movements in the case of the German electricity transition (Kivimaa et al., 2021). The double transition process of, on one hand, niche construction and, on the other hand, regime stabilization has informed a typology of possible user types developed by Schot et al. (2016).

3.2. *A typology of user types in transitions*

Schot et al. (2016) have developed a typology based on a broader literature review of the various roles that users have had in energy transitions, also drawing on the history of technology (e.g. Oldenziel and Hård, 2013), and which was presented to be explored in further empirical research. An important addition of the typology to much of the innovation research on users is the suggestion that users play a role throughout the *entire* transition process, i.e. not merely as adopters or consumers of a new innovation or service. Users are thus not only important actors in the start-up phase and the final stabilization phase of transitions, but also during the acceleration phase. The typology consists of five different user categories: user-producers, user-legitimators, user-intermediaries, user-citizens and user-consumers. We explain each of them in turn (see also Fig. 1):

User-producers are expected to play a pivotal role in the start-up phase of a transition by inventing and tinkering with new, radical technologies. They play a key role in emerging niches, as by experimenting with new technology, they also create new technological and organizational solutions. While user-producers often act alone, they may use external support such as subsidies and tax benefits. Lastly, by articulating new user preferences, user-producers enable the emergence of new routines.

User-legitimators shape and provide meaning and purpose for the activities of niche actors. They act as translators who can interpret landscape, and regime level, developments into more digestible and accessible narratives. As Schot et al. (2016) describe, user-legitimators "*help to anchor expectations and make them more socially robust regarding the viability and significance of the niches*" (p.4). User-legitimators are important in the start-up phase of a transition when expectations, visions, and stories relating to new niches are created and developed, and thus provide legitimation for the emergence of new routines and markets.

User-intermediaries "*create space for the appropriation, shaping and alignment of the various elements of emerging socio-technical systems, such as products, infrastructures and regulatory frameworks*" (Schot et al., 2016, p.4). They are important actors in the acceleration phase of a transition, when expectations and interpretations of new technologies are voiced, designs re-configured and regulations on use developed. User-intermediaries shape user routines and preferences, help to codify them, create user representations, and connect different actors.

User-citizens are active supporters and lobbyists for a particular niche, often acting against a prevailing regime and even other niches. Their main aim is to create regime-shifts and related reforms in support of the niche they advocate for, working with other actors such as elites and social movements. Their work is often challenging, involving "*a struggle to overcome defensive strategies of regime actors in government and businesses*" (Schot et al., 2016, p.4-5). User-citizens become particularly relevant in the acceleration phase of a transition where they challenge the dominant system.

User-consumers enable the stabilization of new regimes by using new innovations and embedding them in their daily practices, confirming and adopting new user practices and routines. They sometimes test new innovations with other users and share their experience with others. "*User-consumers express their status and identity by attributing symbolic meanings to new technologies* "(Schot et al., 2016, p.5), cementing new innovations' social and cultural importance.

Only one published study has explored the full typology with empirical data. Kanger and Schot (2016) examined the diffusion of automobiles in the United States, testing the role of users in the stabilization of niche rules and the destabilisation of regime rules as key transition dynamics. Their study, based on historical secondary data, found that "*the typology of user roles was shown to be a useful analytical device for making sense of the different ways in which users are implicated in systems change*" (Kanger and Schot, 2016, p.609). Kanger and Schot (2016) showed that user-producers and user-legitimators were more salient in the start-up phase of a transition, while user-intermediaries, user-citizens and user-consumers' roles became more evident in the acceleration phase, and lastly, user-consumers dominated the stabilization phase. This work thus confirmed the typology. In our research, we have focused on exploring the various user roles in heat pump transitions, providing a second more systematic exploration because it examines two contrasting subcase-studies: Finland and the UK.

In this study we focus on the role of users for nurturing the niche as well as regime destabilisation. For niche construction users can actively support the development of the technology, with spill-overs into shielding since when users generate a market, passive shielding takes place, and active shielding can be phased out. Niche empowerment is taken into account by a focus on regime resistance: we ask the question to what extent regime actors were open to working with niche actors and nurturing the niche. This lack of resistance also represents the last phase of regime destabilisation as conceptualised by Turnheim and Geels (2013). In their model, regime actors are exposed to external pressures, get performance problems and then loose commitment to the regime which results in less resistance to change, and investment in the niche. This then leads to the empowerment of the niche.

4. Research design and methods

4.1. Case study selection

As our literature review has already revealed, both Finland and the UK are wealthy, Northern European countries, with advanced socio-technical energy systems based on liberalised markets, and a variety of energy generation sources and technologies. They also share the objective of reducing carbon from the energy system, while ensuring energy security (e.g. Hannon, 2015). Both countries also have long-term energy and climate change policies with clear targets for emissions reductions (Kern et al., 2017). While the countries vary in geographical size and population size, their energy demand profiles for households are rather similar, with over 60 % of energy demand required for space heating in both countries.

However, there are large differences in terms of housing and heating regimes, with Finnish homes using more electricity, derived heat and renewables, while gas consumption is high in the UK (see Table 1 and Fig. 2 for more details). The literature we have discussed largely assumes that it is these structural differences (energy demand, gas infrastructure in the UK, cost differences) which explain the divergent outcomes, but with the added point that differences are not a natural function of varying contexts, but are a result of policy choices of the past. Only for the Finnish case it has been argued that the choice for heat pumps was made possible due to a lot of active user involvement. Our case study research will thus not only seek to corroborate this finding for the Finnish subcase, but to elaborate on it by exploring the role of various users following a typology by Schot et al. (2016). To strengthen our findings we also examine a contrasting UK subcase and by doing so, explore the role of various users in a more systematic and symmetrical way.

4.2. Qualitative data collection

Our data collection is based on a comparative, mixed-methods (e.g. Small, 2011), qualitative case study involving empirical data collection, document analysis (e.g. government policy documents, heat pump associations' publications, manufacturers' websites) and archival online sources. In order to examine the role of users in transitions, we chose heat pumps in the UK and Finland since this

Table 1
Key indicators for energy and housing in Finland and the UK.

Indicator	Finland	UK
Population	5.5 million	63 million
Number of homes[a, d]	3 million	27.6 million
Energy use (kg of oil equivalent per capita) in 2015[b]	5924	2764
Share of final energy consumption in residential sector by type in 2016[c]	Space heating: 66.4 %	Space heating: 61.4 %
	Space cooling: 0.1 %	Space cooling: 0.0 %
	Water heating: 15.1 %	Water heating: 18.3 %
	Cooking: 1.0 %	Cooking: 2.8 %
	Lights and appliances: 12.4 %	Lights and appliances: 17.5 %
	Other: 5.0 %	Other: 0.0 %
Fuels in final energy consumption in the residential sector in 2016[c]	Electricity: 25.6 %	Electricity: 6.8 %
	Derived heat*: 34.5 %	Derived heat*: 0.2 %
	Gas: 0.6 %	Gas: 76 %
	Solid fuels: 0.1 %	Solid fuels: 2.2 %
	Oil & petroleum: 7.7 %	Oil & petroleum: 9.2 %
	Renewables & waste: 31.5 %	Renewables & waste: 5.6 %
Average electricity price per kWh[c]	0.16 Euro / kWh	0.19 Euro / kWh
Illustrative starting price of an air source heat pump (installed) [e, f, *]	From 1500 Euros	From 5500 Euros
Average household income per year in 2018[g]	24, 544 Euros	21,464 Euros

Source: [a]Tilastokeskus (2019); [b]The World Bank (2019); [c]Eurostat (2019a,b); [d]Office for National Statistics (2019); [e]Vattenfall (2019); [f]Household Quotes (2019), [g] Eurostat (2020a,b).

**The costs of heat pumps vary depending on the type of a pump (e.g. air-to-air or air-to-water), size of a pump and installation costs, meaning our calculations here are average approximations only.

* Eurostat defines derived heat as follows: "Derived heat covers the total heat production in heating plants and in combined heat and power plants. It includes the heat used by the auxiliaries of the installation which use hot fluid (space heating, liquid fuel heating, etc.) And losses in the installation/network heat exchanges. For autoproducing entities (= entities generating electricity and/or heat wholly or partially for their own use as an activity which supports their primary activity) the heat used by the undertaking for its own processes is not included." (Eurostat, 2020a,b).

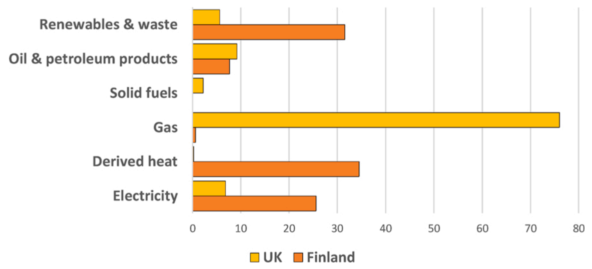

Fig. 2. Share of fuels in final energy consumption for residential heating.
Source: Eurostat (2019b).

provides an embedded case study with two contrasting subcases of an energy transition: one at the start-up phase (the UK) and a case where a transition is at an acceleration/ stabilization phase (Finland). This allows us to explore our research questions and test the user typology (e.g. role of various user roles in various transition phases), including the importance of user-intermediaries and user-citizens for the acceleration of a transition, and in particular the stabilization of routines preceding a wider adoption. We would expect that if all user roles are articulated in the start-up case (e.g. heat pumps in the UK) clearly they are not crucially important for the transition to happen. At the same time, if these user roles are not well articulated in the acceleration/ stabilization case (e.g. heat pumps in Finland) we come to the same conclusion. In other words we expect a substantial difference between the cases because both have such contrasting outcomes.

Our original data collection centred on using four types of sources in tandem in both countries. This included two types of interviews (with experts and households) during February and April 2019 with a total of 52 respondents, document analysis and archival online data:

Expert interviews. For context and background about each transition, as well as opinions about why each transition unfolded the way it did, 11 experts were interviewed in Finland and 13 in the UK. These included representatives from academia and research institutes, government agencies, and trade associations representing the heat pump industry, manufacturers and installers (see Table 2). Expert interviews were either conducted in person or by phone, and lasted between 30 and 90 min. All our interviewees were asked to read an Information Sheet and sign a Consent Form before each interview, and full ethical approval was received for the research from the University of Sussex. We used a semi-structured interview format and interview questions centred on: the heat pump transition; how it has developed in each country; what networking and learning processes have taken place; what expectations experts have for heat pumps; and what the role of users has been in the heat pump transition. Interviews in England were conducted in English and in Finland in Finnish (one of the authors speaks both languages). All interviews were digitally recorded and transcribed. The Finnish transcripts were also translated into English for the purposes of having a common archive. Expert interviewees are referred to in our paper as UKExpertN for experts in the UK and FINExpertN for experts in Finland.

Household interviews. To gauge users' views, 14 heat pump adopters were interviewed in each country, with a geographic spread that included both urban and rural locations. User interviewees also included a range of households (e.g. single person households, couples and families, with a mix of working age and retired people). Two of the UK users were in the process of acquiring a heat pump, while all other interviewees in both countries had used heat pumps to varying degrees of time. All users in Finland were homeowners. In the UK one user was living in a rented accommodation (which had a heat pump) while he was renovating a house he owned (which was also going to have a heat pump). User interviews were either conducted in person or by phone, and lasted between 20–60 min. We used a semi-structured interview format and questions were asked on the following topics: motivations for getting a heat pump; what information and knowhow heat pump users needed in regards to their heat pump installation; whether users had shared their experience of having a heat pump with others; and what their expectations were regarding heat pumps. We collected photos of heat pump installations from interviewees in order to get a better understanding of user context, a few of them are included in this article (See Figs. 4–7). As with the expert interviews, household interviews too were conducted in English in England and in Finnish in Finland. All interviews were digitally recorded and transcribed, with the Finnish transcripts also translated into English. User interviewees are referred to in our paper as UKUserN for users in the UK and FINUserN for users in Finland.

Table 2
List of interviewed expert organisations.

Sector	Finland	UK
Academia	4 (one with industry background)	3
Government department	2	2
Consultancy		2
Industry association	1	2
Heat pump suppliers and installers	3	3
Research & development	1	1
Total	**11**	**13**

Source: Authors.

Table 3
List of online forums.

Country	Online forum	Sector	Link*
UK	Green Building Forum	Anyone	http://www.greenbuildingforum.co.uk/newforum
UK	Moneysavingexpert / Energy section	Anyone	https://forums.moneysavingexpert.com/categories/energy
UK	Build Hub / Renewable Home Energy Generation	Anyone	https://forum.buildhub.org.uk/forum/33-renewable-home-energy-generation/
UK	Navitron Renewable Energy and Sustainability Forum	Anyone	https://www.navitron.org.uk/forum/index.php/board,12.0.html
UK	Superhomes	Anyone	http://www.superhomes.org.uk/forum/forums/general-discussion/
UK	The Farming Forum / Renewable Energy	Farmers	https://thefarmingforum.co.uk/index.php?forums/renewable-energy/
UK	HVAC-Talk / Forum: Going Green: Geo Thermal / Water Source	Heating, ventilation and air conditioning installers	https://hvac-talk.com/vbb/forumdisplay.php?332-Going-Green-Geo-Thermal-Water-Source
UK	Electricians forum / Renewable Heat	Electricians	https://www.electriciansforums.net/
Finland	Lampopumput - Keskustelua lämpöpumpuista [Heat pumps forum]	Anyone	https://lampopumput.info/foorumi/
Finland	Maalämpöfoorumi [ground source heat forum]	Anyone	https://www.maalampofoorumi.fi

Source: Authors.
* All links accessed on 15.04.2020.

Document analysis. To triangulate the original data but also to help contextualize each transition and to better understand the policy environment, we collected and compiled multiple texts to supplement our empirical work. These texts included government policy documents on heat and energy policy (e.g. Department for Business, Energy and Industrial Strategy in the UK and Ministry of Economic Affairs and Employment in Finland), reports about heat pump trials, industry reports and academic literature. We also used documents from non-governmental bodies that have produced reports on heat pumps (e.g. EST, HPA, GSHPA, SULPU, European Heat Pump Association). Both English and Finnish documents were included. We also included relevant academic literature based on key word searches in Scopus, Web of Science and Google Scholar, using the following keywords: heat pump*; user*; Finland; United Kingdom.

Archival online sources. For both countries, internet archives, internet groups and historical records of online forums used by heat pumps users were also analyzed over a 30-year period. In terms of identifying online user groups, we used the key terms: heat pump*; user* AND forum, both in English and Finnish online searches. We found that while there were two online forums dedicated to heat pumps in Finland, in the UK, discussions were much more spread across online sources that were not specifically catered for heat pumps only but also included other technologies (see Table 3).

4.3. Data analysis

Our data analysis was guided by theoretical assumptions about niche construction (e.g. learning, networking), regime destabilisation, and user involvement, given that these were also reflected explicitly in our research interview questions. We used thematic coding and analysis as the main method of analysing our data. Thematic analysis was chosen as it allows for clear structure to emerge from findings (Sovacool et al., 2018). All expert interview transcript were uploaded to NVivo software where they were coded following our key interview topics of: historical development of the heat pump sectors in each country; developments in policy specifically supporting heat pumps; evidence of networks; evidence of shared learning; and evidence of activities by users. To operationalise the typology on different users, we first identified users present in each case, based on our interview data, document analysis and previous literature. These were then categorised according to their key activities, as presented in Table 4. In addition, user interviews were coded in terms of: users' motivations to install a heat pump; what learning they needed to install a heat pump; what expectations they had for their heat pumps; and whether there was evidence of networking amongst users. Following our thematic analysis, a historical narrative on each heat pump transition was written, paying particular attention to user roles within each transition phase.

4.4. Limitations

As is common in academic research, one project cannot provide all answers. There are thus inevitably some limitations to our study. Here we outline two main ones. First, given our research budget and project timelines, we focused only on one low-carbon technology in two countries in both our literature review and data collection. While this provided a focused, and also a rich, dataset, it also meant that we did not consider other technologies or countries. Second, we explored the various user roles based on one type of user typology (by Schot et al., 2016). We chose this as it was a peer-reviewed study published in *Nature Energy* that directly examined users in low-carbon transitions and specifically welcomed further empirical research on this topic. Our case study comparison suggests that different user roles are key to understanding differences between the two case countries. However, future research, including other countries too, should consider this particular factor in relation to possible other factors that may have a part in explaining the difference (e.g. geography, climate, policy, infrastructure, culture etc.). We therefore welcome further research on users in low-carbon transitions that involve other technologies, country contexts, factors, and methods.

Table 4
Operationalising the user typology for heat pump transitions.

User types	Most relevant transition phase	Key activities	Main codes	Empirical example
User-producers	Start-up phase	- *Invent, experiment and tinker* with new radical technology - *Create* new technological and organizational solutions - *Articulate* new user preferences - Often act on their own - May use external support such as subsidies and tax benefits	- Invent - Experiment - Create organizational solutions - Articulate preferences - Use of support	- A pioneer building a heat pump - An actor setting up first body representing heat pumps
User-legitimators	Start-up phase	- *Interpret and narrate* developments at landscape level such as climate change - *Create visions and stories* for new niches	- Interpreting - Narrating - Visioning	- Users feeding supportive heat pump stories to media and other public domains
User-intermediaries	Acceleration phase	- *Configure systems* by tinkering with design of new technologies - *Set and shape user rules*, routines and preferences - *Connect* different actors	- Reconfiguring - Setting user rules - Connecting actors	- Actors sharing experience on suppliers and installers to other users - Users sharing tips to other users on how to modify heat pumps
User-citizens	Acceleration phase	- *Active support and lobbying* for a particular niche/technology - Often acting against and *confronting* a prevailing regime - Work with other actors such as NGOs, elites and social movements	- Lobbying - Confronting regime - Co-operating with NGOs	- Actors lobbying key stakeholders for policy change to support heat pumps - Users demonstrating on behalf of heat pumps and against fossil fuel heating systems
User-consumers	Stabilization phase	- *Buy products and embed them* in their daily practices - *Express status and identity* by attributing symbolic meanings to new technologies - Might work together with other users in consumer organisations to test products and systems and share information	- Everyday consumer - Expressing status	- Users considering heat pumps as a normal and expected part of a heating system - Users showing off their heat pumps to others

Source: Based on Schot et al. (2016).

5. Results: the role of users in two contrasting heat pump transitions

We present our results and discussion in two distinct parts of the paper. In this section, we provide a chronological history of the development of the heat pump transition in Finland and the UK, paying particular attention to the roles of users in both cases. In the section to follow, we draw from these cases to reflect more broadly on core themes including exploring the different user roles, niche construction, regime destabilisation, and divergence in heat pump pathways.

5.1. The heat pump transition in Finland

Based on previous literature (e.g. Lauttamäki and Hyysalo, 2019), our interviews and diffusion figures of heat pumps we distinguish three phases in the heat pump transition in Finland. The *start-up phase* (1975–1985) of a heat pump transition in Finland began with first heat pump pilots and experiments took place in Finland mainly with GSHPs in the 1970s following global oil crises and experiences from neighbouring Sweden (FINExpert07). The government supported energy innovation funding also in GSHPs and Finland had about 15 small GSHP manufacturers (see also Majuri, 2016). People *"were already talking about heat pumps in the public and there were news stories"* (FINExpert10). At this stage, those installing heat pumps were largely ***user-producers***, "*progressive people who dared to have geothermal heat*" (FINExpert10) and were motivated to experiment new technology that was not dependent on oil. These small technical experiments continued in the 1980s, though never really took off due to technical difficulties with GSHPs technology (FINExpert03). Most of the 15 GSHP suppliers at the time were small companies with limited financial resources (FINExpert10), and following oil price drops in the mid-1980s, many faced bankruptcy (FINExpert10). In addition to technological uncertainty and limited resources, this period was also clouded by negative narratives in the media (FINexpert07). Research effort too was affected with limited funding available post 1980s (FINExpert10).

However, some people persisted, and two new manufacturers were established in the 1980s, one of which in particular was "*doing wide-ranging work, going around building fairs and doing grassroots work*" (FINExpert10). The influence and example of Sweden was important in the start-up phase: "*In the 80 s we were clearly behind Sweden and all the innovations and new solutions came from Sweden.*" (FINExpert06). An estimated 10,000 ground source heat pumps had been sold by 1984 in Finland (Lauttamäki, 2018).

The acceleration phase (1995–2015) of heat pumps started in the mid-1990s, with increased activity from early 2000 onwards (FINExpert10; see also Kivimaa et al., 2019b). Further influence came from Sweden, which was 'testing' the product, creating a market and had supportive policies (FINExpert06), such as "*technology procurement, municipal and national energy advisory services, and a subsidy scheme for the phase-out of oil boilers*" (Heiskanen et al., 2011, p.176). One expert explained the influence from Sweden as "*the fact that Swedish is read in Finland and the events in Sweden are being followed in Finland has brought innovations from Sweden … Swedish speaking and the Swedish media have influenced this*" (FINExpert06). User-producers continued grassroots level activity in testing new technology, often against adversity: "*even in the 90's it was only a few who dared to try new things … there were these grassroots actors who were traveling around at these fairs, they really did a lot of work and really faced a lot of doubt*" (FINExpert10). In addition to GSHPs, also ASHPs were entering the Finnish market and there was "*better technology available which helped a more sustainable growth path*" (FINExpert10). A few Finnish heat pump manufacturers and those exporting from other countries emerged too, (FINExpert03; FINExpert05). The Finnish Heat Pump Association SULPU was established in 1999, again following the example from Sweden—the Swedish branch of the International Ground Source Heat Pump Association (IGSHPA Sweden) for example had been established in 1987 (KTH, 2019). The main motivation of SULPU was to bring different heat pump actors together and create a new sector. As one founding member of SULPU recalled: "*The sector did not exist in 1995. If it had not been there in Sweden, I doubt you would have had the courage to get involved. We really started from scratch. If we think that 50 pumps were sold in all in Finland, so in reality there was no sector at all.*" (FINExpert05).

In the early 2000s, there was still a lack of awareness of heat pumps amongst the public (FINExpert02), with many doubting ASHPs' suitability in a cold climate (see also Kivimaa et al., 2019b). SULPU and the Finnish energy efficiency agency Motiva especially set out to raise awareness (FINExpert05; FINExpert06). Their other aims were to encourage the development of standards, create training for installers, collect statistics and build visibility through supportive narratives – effectively also acting as ***user-legitimators***. As the technology failure of the 80 s was overcome in the 2000s with better performing products that also proved to work in the cold Nordic climate, "*larger numbers of people dared to start investing*" in heat pumps (FINExpert10). This was supported by technological advances, including better borehole drilling technology for GSHPs (FINExpert06). Government incentives included taxing fossil fuel based heating oils and in 2003 subsidies were introduced to encourage a switch from oil-based heating (e.g. Kern et al., 2017) which made heating with "*heat pumps [cheaper] than with oil*" (FINExpert01). Many of these were removed in 2012 for all but low-income households though (e.g. Kern et al., 2017). The main financial support mechanism, a 'deduction of household expenses', was introduced in 2001 and remains one of the longest standing support mechanisms also aiding the installation of heat pumps (Lauttamäki, 2018). At the same time, many users set up online internet forums (Hyysalo et al., 2018), motivated by the need to create independent platforms which allowed the sharing of user experience through ***user-intermediaries***. Heat pumps were also officially included as a renewable energy source in the European Renewable Energy Directive in 2008, for which SULPU lobbied for (FINExpert05). Indeed, Heiskanen et al. (2011) even call the years 2006–2008 as the "breakthrough stage" for heat pumps in Finland.

Heat pumps sales in Finland have seen a steady increase since 2010 (see Fig. 3). In 2019, 930,000 heat pumps had been sold, rising to over a million in 2020, and providing "*a significant share of [Finland's] renewable energy, about 5 TWh*" (FINExpert03). The market

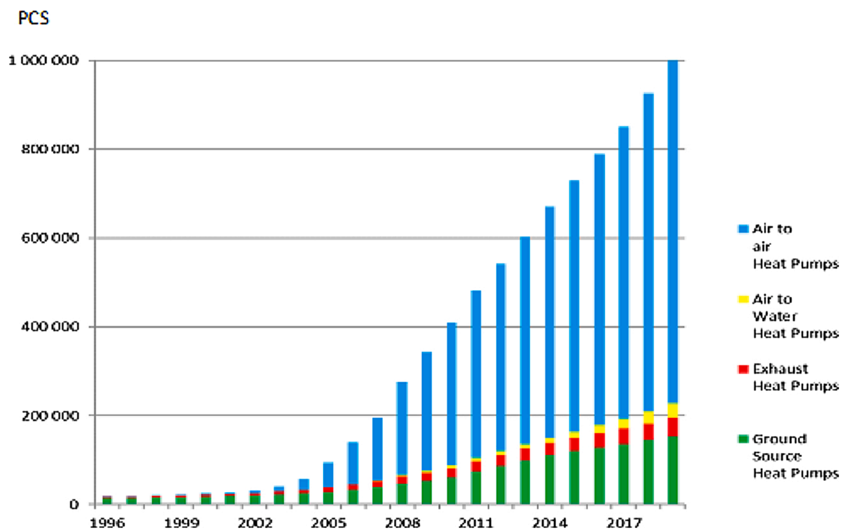

Fig. 3. Heat pumps sold in Finland (2004-2019).
Source: SULPU (2020c).

Fig. 4. Heat pump reseller in Kuopio, Finland.
Source: Authors.

entered the stabilization phase (post-2015) and has become established with large-scale companies offering turnkey services (see Fig. 4 illustrating products available from a heat pump installer). Our data suggests that it is very easy for ***user-consumers*** such as individual householders to choose heat pumps, whether an ASHP or GSHP, and they have become a popular choice for many householders who have wanted to install affordable heating systems that are easy to maintain and provide even heat provision throughout the house. Many households have also installed heat pumps as hybrid systems. These are often combined with wood burning fireplaces (especially ASHPs) (see Figs. 5 and 6 showing heat pump installations in two Finnish homes). While Finland has a high heating demand for the majority of the year, heat pumps are also increasingly installed to meet cooling demand in the summer months, driven by more air tight and energy efficient housing and climate change (FINExpert02; FINExpert04).

Fig. 5. An ASHP inside unit at a family home in Finland.
Source: Authors.

Fig. 6. An ASHP outside unit installed in Finland.
Source: Authors.

5.2. The heat pump non-transition in the UK

As in Finland, heat pumps started to receive more interest following the 1970s oil crises, (UKExpert07), but they have faced many obstacles since their introduction, including technological challenges, lack of awareness and the power of other energy incumbents, most notably the gas heating sector. Based on the literature (e.g. Gross and Hanna, 2019), our interviews and diffusion figures, it is clear that the heat pump transition in the UK has remained stuck in the start-up phase. One of the first heat pump installers in the UK recalled resistance to the technology in the 1970s even from those who were examining other renewable energy technologies, like the Centre for Alternative Technology (CAT), a pioneering intermediary of low energy housing and renewables in the UK (e.g. Martiskainen and Kivimaa, 2018). As UKExpert07 explained, "*CAT were always a bit sceptical of heat pumps, because it could mean more electricity. So, there was sort of caution with heat pumps*." (UKExpert07).

Even though a small number of heat pumps were installed throughout the 1980s and 1990s, the numbers remained limited and were often driven by enthusiasts and grassroots actors motivated by the desire to save energy by building and testing new technology. For example, one UK heat pump ***user-producer*** initially built and tested small air source heat pumps in his own house throughout the 1980s and early 1990s, to see how the technology works and how it could function in the UK context. He also visited Sweden, where more heat pumps had been installed, to learn about the technology. He built and installed approximately 50 heat pumps for other users but stopped in 1995 "*when CE Marking came in, because there were too many regulations for me*" (UKExpert07). Unlike in Finland, this user-producer did not have other user-producers at hand to support him and largely operated on his own with limited networking.

Heat pumps started to gain some more interest in the 2000s (UKExpert14), but still "*the numbers [were] very slow if you compare to any other country in Western Europe*" (UKExpert14). The limited amount of heat pump adoption in the UK was linked by UKExpert04 to a lack of legislation in regards to buildings: "*until the legislation really catches up, certainly on new build, there's not an awful lot driving people going to heat pumps.*" (UKExpert04). During the first half of 2000s, there was a lot of interest towards developing policies for supporting microgeneration (i.e. renewable energy generation less than 50 kW). The government for example funded technical research by the Energy Saving Trust (EST) which predicted in 2004 that microgeneration could provide 30–40 % of the UK's electricity by 2050 (DTI, 2006). GSHPs were given policy support with a reduced 5% VAT rate in 2004, and ASHPs in 2005, and a government Microgeneration Strategy was published in 2006 (DTI, 2006). The Strategy recognised the lack of large-scale manufacturing based in the UK and outlined the need to examine the motivations of early adopters. Consecutive grant programmes such as the Clear Skies (2003–2008)[2] and Low Carbon Building Programme (LCBP) (2006–2010) provided grants. Both programmes also had certified installer registrations linked to them with an aim to develop standards.

At the same time, the Ground Source Heat Pump Association (GSHPA) was established in 2006 consisting largely of GSHP installers, with the main aims of promoting GSHP technology, raising awareness, organising training, and creating networking activities—in effect acting as an early ***user-intermediary***. In 2007, a Microgeneration Certification Scheme (MCS), a quality assurance scheme was launched and required all LCBP funded projects to use MSC certified products and installers (MCS, 2019). In 2006, a Labour government also announced that from 2016 onwards all new buildings would be zero carbon, starting with a voluntary building code, the Code for Sustainable Homes (e.g. Kivimaa and Martiskainen, 2018).

In order to analyse ASHP and GSHP performance in real-life situation, the government also funded two small technical trials, run by EST between 2008–2013 (Dunbabin and Wickins, 2012; Energy Saving Trust, 2013; Roy et al., 2010). These trials, perhaps surprisingly, found that within the UK, the performance values monitored for heat pumps varied widely, and that the system efficiency figures for the sample of GSHPs were lower than those monitored in similar European field trials (Roy et al., 2010). They also examined how

[2] From 2002, a "Major Photovoltaics (PV) Demonstration Programme" ran alongside Clear Skies supporting solar panels.

Fig. 7. An ASHP outside unit installed in the UK.
Source: Interviewee.

users perceived the technology, noting that "*many householders said that they had difficulties understanding the instructions for operating and using their heat pump*." (Roy et al., 2010, p.6) and that "*there were several clear examples of poor control*" of heat pumps, and of users using domestic hot water excessively (Love et al., 2017, p.xv). Lowe et al. (2017) further found that even though most homes reported being satisfied with their heat pumps, 10 out of 21 cases had experienced some type of problem since installation. These factors suggest perhaps that users could not rely enough in installers, or other users and user organisations to assist them in navigating these problems.

To induce market development, in 2010, further policy support was introduced in the form of a feed-in-tariff (FIT) for renewable energy generation, and in 2013, a Green Deal was launched to encourage households to undertake energy renovations. UKExpert11 noted that while the government promoted heat pumps around this time, there was still a more fundamental lack of action on decarbonising heat, with people having discussed for example "*expanding the amount of district heating in this country since The Second World War*" (UKExpert11). In 2014, the LCBP was replaced by a Renewable Heat Incentive (RHI), which introduced seven-year payments to renewable heating systems, with the aim of reducing emissions, but also providing further learning and development of the heat pump market (see BEIS, 2018a, 2018b). Following a stark change in policy in 2015, a Conservative government removed the zero carbon homes objective and the complicated and costly Green Deal (e.g. Rosenow and Eyre, 2016; Kivimaa and Martiskainen, 2018). Furthermore, the FIT was closed for new applications in April 2019. RHI hence remains the main support mechanism for heat pumps.[3]

Many of our interviewees said that despite these policies and strategies, there is still no heat pump transition in the UK (UKExpert01; UKExpert05; UKExpert09; UKExpert10), or it has been a very slow transition (UKExpert04; UKExpert11; UKExpert12). As UKExpert01 explained: "*At the moment I would not call it a transition, because it's a bit too optimistic. There have been field trials, some financial incentives for people to install heat pumps and be paid for the heat, but calling it a transition is a bit optimistic as there are not very many installed*". The UK Heat Pump Association (HPA) estimates that around 163,000–170,000 heat pumps have been installed in the UK in the past 20 years—though some of our interviewees estimated the total at 200,000, but there are no official statistics available (UKExpert06; UKExpert12). As UKExpert03 explained: "*the data set is incomplete, so, it's very difficult to establish what the real marketplace looks like*". While Ofgem has publicly available data on RHI installations and consultancy BSRIA for example has historical heat pump installation data available behind a paywall, "*there's no central requirement to record any of this stuff*" (UKExpert03).

In any case, the estimated 20,000 annual heat pump installations (UKExpert06) is a very small number compared to the 1.5 million

[3] As per Ofgem rules, the RHI is only available for heat pumps used for space or water heating: https://www.ofgem.gov.uk/environmental-programmes/domestic-rhi/applicants/eligible-heating-systems [Accessed 23.08.2019]

gas boilers sold each year (Lipson, 2018) (Fig. 7 shows an example of a domestic heat pump installed in the UK). Heat pumps in the UK thus remain a niche, as noted for example by the independent Committee on Climate Change (CCC) (2019) which monitors the UK's progress in relation to its climate targets, and highlighted in 2019 that: "*over ten years after the Climate Change Act was passed [2008], there is still no serious plan for decarbonising UK heating systems and no large-scale trials have begun for either heat pumps or hydrogen*" (Climate Change Committee 2019, p.12).

6. Discussion: Users, niches and regimes in heat pump transitions

With our cases presented, this section delves more deeply into our three main research questions: the roles of users; whether and how identified user roles have contributed to niche construction and regime destabilisation; and the explanatory power of user involvement for the divergent heat pump trajectories in Finland and the UK.

6.1. Testing the typology of user innovation

We set out to examine the role of users in transitions, focusing on heat pumps in Finland and the UK, and using a user typology developed by Schot et al. (2016). Our findings show that most of the user roles are evident in Finland, particularly ***user-producers, user-legitimators, user-intermediaries and user-consumers***. In the UK, however, apart from ***user-producers***, the other user roles are almost missing or appear rather weak.

Our analysis shows that ***user-producers*** tend to be most prominent in the start-up phase of a transition when new technologies are being invented, built, tested, and experimented with. We identified user-producers in both countries in the start-up phase who built and tested new technology, driven by motives such as saving energy, using fossil fuel free heating systems, or proving whether or not heat pump technology works. In Finland, for example users such as the establisher of the heat pump association SULPU became an entrepreneur after experimenting with heat pump technology in his own house back in the early 1990s. At first, he was sceptical about the technology working, so he was motivated to test it himself, buying a heat pump in 1992 from Sweden. For the next 11 years, he kept a daily data of his heat pump generation and weather conditions, building his own IT model to analyse his consumption.

> "*I was sitting in a pub [in 1992] and there was a Swedish-speaking guy from Kauniainen in the pub. And he said he was installing air source heat pumps in Sweden. And of course as a person in energy technology I had heard the word heat pump, but not much more. And I told him, after talking with him for a while, that don't bullshit an energy technology engineer, that no significant amount of energy is being released from the outside air. And the argument got so far that the only way to solve it was to get a pump from Sweden and install it in my house. He even did the installation.*" (FINExpert05).

Through his establishment of SULPU, he was able to articulate preferences in terms of realising that as an entrepreneur he needed to develop cooperation in the sector. User-producers in the early 1990s in Finland could for example share their experience of heat pumps through activities such as attending building fares and heat pump days (e.g. Martiskainen, 2014). Showing examples to other users of what can be achieved with heat pumps was important at this phase of a transition. As one user-producer explained:

> "*At first you have to find the pioneering customers. In fact, they are there as long as you can get information flowing, they are those who want something different, visionaries. I found a few of those, I also did get some drunks and crazy customers, but the more information you had, the more customers you got. Many people wanted to try them to see if they make sense. So that you can show off to your neighbours and stand out from the crowd. So those were the first types of customers.*" (FINExpert05).

Another expert attributed the success of heat pumps in Finland partly to:" *Suitable conditions, active entrepreneurship, and institutional entrepreneurship represented by the founder of SULPU*" (FINExpert06).

In the UK's current start-up phase, most of the users we interviewed were user-producers motivated by saving energy, testing heat pump technology in practice, and also sharing experience with others to some extent. User-producers in the UK go as far back as the late 1970s, when heat pumps were first experimented with. One user-producer for example built and installed his first heat pump in the 1970s: "*the first heat pump I ever installed was, maybe 1978, in my parent's kitchen in Northwest London when I was doing refrigeration. I did actually install a little one just in the wall in the kitchen. I learned a lot from that.*" (UKUser01). While that user-producer for example built and installed several heat pumps for other users, he did not take an active role in articulating preferences for the wider sector but rather tested and installed technology at a smaller scale. Many early heat pump users in the UK have been motivated to also test other new technology. For example, several users we interviewed also had solar PV and electric vehicles (EV) and they were very aware of their energy consumption, using tools such as grid carbon intensity mobile apps to optimise energy consumption (UKUser02; UKUser12; UKUser13).

Our findings show that user-producers have been more focused in supporting each other and connecting with each other at the start-up phase in Finland than in the UK, especially through heat pump specific online user forums (e.g. Hyysalo et al., 2018). In the UK, such online forums dedicated for heat pumps alone do not exist, but instead heat pumps are discussed in various different types of online groups and on social media. In Finland user-producers also seem to be more dedicated to heat pumps, focused on building a constituency behind the heat pump transition.

As per ***user-legitimators***, we identified little evidence of these in the UK than in Finland. User-legitimators in Finland have shared their experience and stories of heat pump use more widely in the media, for instance, encouraged by SULPU: "*The visibility is a big thing and we take care of it via press releases, events and social media. Social media has a whole other role in that it is also read by journalists who pick up story lines.*" (FINExpert05). However, two experts noted that heat pumps did not get as much media attention nowadays as solar power for example (FINExpert06; FINExpert07), with one saying: "*solar power gets a lot of attention in the media, but [SULPU] doesn't get* *so much attention*" (FINExpert07). The narrative on heat pumps in Finland is much stronger and now moving from heating to also cooling opportunities, whereas in the UK these narratives are not as visible in mainstream media, though some of the householders we interviewed have shared their experience via social media (e.g. Twitter) and personal blog posts. For example, our UK interviewees remembered only one heat pump advertising campaign by a utility.

User-intermediaries have been clearly evident in the acceleration phase in Finland, demonstrated especially through the initial establishment of SULPU by a user-producer who later became a user-intermediary, and by the set-up of online user forums by citizens (see also Hyysalo et al., 2018). SULPU was particularly motivated to create a sector, develop standards, increase awareness, provide learning in the form of statistics and training, and access policy support. Online user forums, meanwhile, were there to provide peer-to-peer sharing and keep standards in check. In other words, these user-intermediaries have improved the heat pump sector in Finland into a more coherent segment of the Finnish low-carbon transition. In the UK, however, such dedicated user-intermediaries seem scarce. A few of the users we interviewed have set up blogs and websites, and shared their heat pump experience on social media, but there is limited collective action by user-intermediaries in the UK—perhaps also reflecting the fragmented nature of the industry itself.

As for ***user-citizens***, our interviews did not identify these strongly in either country, but some activity has been visible. In particular in Finland, the establishment of SULPU helped to bring a disparate sector together and created a voice for lobbying that led to supportive government policies. These have provided concrete subsidies such as tax breaks on purchase loans and the installation costs of heat pumps. In the UK, the GSHPA has undertaken some lobbying and in 2019 for example hired the services of a paid lobbyist, but their resources have been relatively limited.

User-consumers are clearly evident in Finland, but lack in the UK. The variety of the UK housing stock and the different types of actors potentially becoming relevant users was reflected on by UKExpert06: "*You talk about users, but with new build I just have to convince a developer and their stakeholders, the architect, and the M&E consultant, and one or two others, and I've suddenly got myself an order for X or Y number of houses. The users then just buy a house, they don't really care what the heating system is. But we're not dealing with users, and we're just dealing with decision-makers. The house purchaser just inherits some slightly different way of producing hot water in their home.*" (UKExpert06).

In Finland, it is now normal to have a new house (especially a detached one) with a heat pump, and they are common in existing buildings too. In fact, our interviewees mentioned that it is now considered strange if people do not choose a heat pump when building a new house for example. So, heat pumps have amassed some cultural and symbolic meaning. However, this is not to the level that fireplaces (which are often combined with heat pumps), or even old oil boilers, for example, have. As one interviewee explained, old oil boilers needed regular maintenance and tending to—and this job historically belonged to "the man of the house" (FINExpert05) showing also gendered aspects— whereas heat pumps in comparison are rather carefree (FINUser01). An installer for example said that he doubts users will sit around their heat pumps in the same way as they would do around their fireplaces (FINExpert08). Another user too had warmer thoughts for his wood logging activity needed for his fireplace, saying that he would hold an axe as long as he could and that his heat pump would not replace that (FINUser13). Heat pumps have nevertheless become a norm, and have been domesticated and integrated into the life-styles of user-consumers. This process is still ongoing. For example, with temperatures rising to +35 C in the summer of 2018, installers in Finland reported heat pump shortages as users were increasingly installing them also for cooling (FINExpert08).

Furthermore, we identified clearly differing motivations for user-consumers to install heat pumps in the two countries (see Table 5). In Finland, user-consumers were mostly motivated by saving money (8/14 interviewees); being able to use a heat pump for cooling (7/14); having heard about heat pumps from others (5/14); wanting more even heat distribution in the home (4/14); having easy maintenance (3/14); being good for environment (3/14); and saving energy (2/14). In the UK, meanwhile, main motivations were

Table 5
User-consumers' main motivations to install a heat pump.

Main motivation to install a heat pump	Finland	UK
Save money	FINU01; FINU02; FIN03; FIN04; FINU05; FINU06; FINU12; FINU14	UKU02; UKU06; UKU07
Use for cooling	FINU01; FINU02; FINU05; FINU06; FINU09; FINU10; FINU11	Not mentioned
Heard about heat pumps from others	FINU01; FINU02; FINU07; FINU08; FINU14	Not mentioned
More even heat	FINU07; FINU08; FINU11; FINU13	Not mentioned
Easy maintenance	FINU05; FINU06; FINU12	Not mentioned
Good for environment	FINU05; FINU06; FINU09	UKU01; UKU02; UKU03; UKU05; UKU06; UKU10; UKU11; UKU12; UKU13; UKU14
Save energy	FINU09; FINU11	UKU01
Government incentive	Not mentioned	UKU02; UKU06; UKU07
Needed a heating system for off-grid property	Not mentioned	UKU04; UKU08; UKU09
Wanted to know how technology works	Not mentioned	UKE01; UKU06
Cleaner indoor air for health reasons	Not mentioned	UKU08

Source: Authors.

wanting to do something good for the environment (10/14); saving money (3/14), getting a government incentive to install a heat pump (3/14); needing a heating system for off-grid property (3/14); wanting to know how heat pump technology works (2/14); and improving indoor air quality (1/14). This shows how financial and comfort motivations dominate in Finland compared to environmental ones in the UK. Theoretically this means that we have many user-consumers in Finland who operate in a new heat pump regime, while in the UK users are operating in a niche and often need specific motivations.

Our answer to the first sub-research question is that an important difference is visible in Finland and the UK in the way users are involved. In the UK users are hardly involved in shaping the transition, while in Finland they have been actively involved, yet two types of user roles are not well developed. The role of user-citizen is completely lacking, while the role of user-legitimator is present, but in a weaker form. Users have thus not developed forceful narratives about the important role of heat pumps in the energy system of the future in either country. Schot et al. (2016, p.5) hypothesize that all of the user roles "*are present throughout the entire transition, but expect that some roles will become more salient in specific transition phases*". Our results show that in the case of Finland, user-legitimators and user-citizens were perhaps not needed. We would like to argue that this is a result of the presence of a housing regime in which heat pumps fitted easily. We will come back to this finding in Section 6.3, and discuss theoretical implications, but before doing that we first discuss how these user roles contributed to two crucial transition processes of niche construction and regime destabilisation.

6.2. *Niche construction and regime destabilisation*

We next discuss how users contributed to various processes of niche construction and regime destabilisation. In terms of niche construction processes, in the case of Finland, strong user-intermediaries have been present to facilitate these processes. The most prominent example of these is the Finnish Heat Pump Association SULPU. As Heiskanen et al. (2011) have noted: "*since SULPU was established, the heat pump sector has started to emerge from fumbling attempts by small local companies to co-operate into a globally relevant industry*" (p.1898). Two user-producers, one an entrepreneur and the other a heat pump researcher, established SULPU in 1999 with support from the Finnish government-affiliated energy efficiency agency Motiva. SULPU's main aim was to create a common organisation that could act as a voice and a facilitator for the heat pump sector. Motiva was an important regime-based transition intermediary (e.g. Kivimaa, 2014; Kivimaa et al., 2019a) by providing a neutral space for the fragmented heat pump companies to come together under SULPU (FINExpert03).

One of the founding user-producers of SULPU had a strong vision and ***expectations*** for the sector: to create a market so that "*Finland would have a million heat pumps in* 2020″ (FINExpert05) – which also came to fruitition. His role developed from a user-producer to a user-legitimator, user-intermediary and even a user-citizen by anchoring and voicing expectations for the market, creating awareness of heat pump technology, lobbying policy makers to put in place supportive policies and working towards changing regime rules. The establishment of SULPU also provided an opportunity for new ***networks*** to emerge, as "*organising supply chains and customer meetings were really important*" (FINExpert05) in the market creation. This also involved linking with other associations, including for example the borewell association Poratek (established in 1995) and the Finnish Clean Energy Association (established in 2013).

In terms of ***learning***, the close ties between Sweden and Finland meant that in the start-up phase of the market, Finnish players were able to look to Sweden to learn about technology, business models, market development and standards. This shows a spatial and transnational aspect to transitions (e.g. Bridge et al., 2013). Such transnational relationships between actors and institutions can facilitate a flow of knowledge, capital and technical resources from one country to another (Wieczorek et al., 2015), contributing to niche development (Hansen and Nygaard, 2013). User-producers in Finland were able to look to Sweden—a similar country with cold winters and high heating demand, and a cultural preference for self-built houses producing homes large enough to accommodate innovative heating systems. In addition to SULPU facilitating training for installers, and raising awareness of the technology through media campaigns, also Motiva has been as an important knowledge bank on heat pumps. Over the years, Motiva has conducted technical research testing technology, organised regular public energy awareness campaigns, provided heat pump certification training, and built an information source on their website including guidelines for those wishing to acquire heat pumps (FINExpert01; FINExpert07). This has been important work as "*those people who test, or do the work on behalf of users, are terribly important. … What Motiva does, or SULPU does, is constructing the market, building the market*" (FINExpert06).

Separately from heat pump industry actors such as SULPU and Poratek, or the government-affiliated Motiva, learning shared via online internet forums largely set up by user-producers in the early 2000s (Hyysalo et al., 2018) has been important. These user-intermediaries have allowed users to connect and share their user experience and answer each other's questions, while also 'policing' market actors (e.g. heat pump suppliers and installers) and scrutinising technical results by research institutes (Hyysalo et al., 2018). Such peer-to-peer support has been important in "*scaling, choosing, comparing, maintaining and modifying*" new technologies (Hyysalo et al., 2017, p.71), to reach beyond early enthusiasts (Heiskanen et al., 2014a; Hyysalo et al., 2013a, 2013b). Our expert interviewees also mentioned the user forums: "*There are regular stories about people's experience and what's interesting in social media. There are large forums where you can easily find out about the technology*" (FINExpert09). However, none of the users we interviewed had been active on these online forums. Many mentioned the internet as a source of information, but the majority said that they had received sufficient information from their local heat pump installers.

The heat pump niche constructors had to overcome some ***regime*** resistance. For example the incumbent oil heating sector took one of the founders of SULPU to court over their marketing in early 2000s which encouraged the replacement of oil boilers with heat pumps (Virkkunen, 2017). Heat pumps also had to compete with other small-scale renewable technologies such as biomass, especially pellet-heated boilers, and solar power. However, "*pellets dropped off the race about ten years ago*" (FINExpert02), and solar power has not followed a similar uptake as heat pumps, even though it is getting more popular (FINExpert11).

An indication that the prevailing regime is destabilised and a new regime has been formatted in Finland is that regime rules have changed to the extent that heat pumps are the new normal amongst user-consumers. Heat pumps have become a tool to heat and cool a home, and to address energy related emissions and climate change. Our interviewees especially mentioned that climate change had dominated the news and political agenda in Finland since the 2018 IPCC report (IPCC, 2018), with people talking about a time before and after 'climate change anxiety' (FINExpert01). As one interviewee highlighted: "*This report has been, in my memory, maybe the biggest single opinion leader in Finland. And for the first time, in my opinion, it could be said that ordinary citizens became conscious of the fact that something really must be done. And individuals, maybe more women, are thinking what they are doing. When money in the past was guiding the purchase of renewable energy in* 90 % *of cases, now green values have clearly increased. Though their share is still quite low.*" (FINExpert02).

Heat pumps in Finland today are "*viewed by the public and experts alike as the normal and rational choice for a heating system*" (Hyysalo et al., 2018, p.880). Following Schot et al. (2016), this indicates that the heat pump market has stabilized, so that "*it has become possible for users to engage in sustainable practices in a habitual and non-reflective manner*" (p.6).

As for the UK, there is large potential for heat pumps, but a lack of awareness remains one of the key barriers, i.e. what a heat pump is, what it can do and how it operates (UKExpert04), in addition to the potential disruption that installing a completely new heating system may cause. This lack of awareness is not limited to the general public but also architects, builders, property developers, heating installers, and policymakers were mentioned as having incomplete knowledge of heat pumps (UKExpert03; UKExpert06; UKExpert11). This can directly shape ***expectations*** of the technology, as well as how the heat pump sector will develop in the future. Experts (UKExpert03; UKExpert04) and two users (UKUser03; UKUser14) for example said that they installed heat pumps in Victorian era housing to dispute the "myth" that heat pumps do not work in the UK's existing housing stock. UKExpert04 also noted the misinformation about heat pumps, with some people for example thinking that ASHPs only work in certain conditions, and that GSHPs suit the UK climate better, indicating that even amongst experts there is disagreement about the suitability of heat pumps in the UK.

The lack of awareness of heat pumps in the UK highlights a need for further ***learning*** in terms of education and building of skills base (UKExpert08). For example, the EST trials completed in two phases between 2009–2013 (Dunbabin and Wickins, 2012; Roy et al., 2010) showed that correct design and installation were more significant than user behaviour in how heat pumps performed (Energy Saving Trust, 2013). Further trials are underway, with the government providing further £3 million in grant funding to examine the possibility of developing gas driven heat pumps, as well as fuel cell driven systems for the UK market (BEIS, 2018a). Industry associations such as the GSHPA and HPA have also provided education and awareness raising, but more action is needed to develop better training. There is training available for installers, but this was not considered to be that good (UKExpert04), partly due to lack of limited heat pump demand (UKExpert06). There is also a need to streamline certification schemes. For example, according to BEIS, there can be a large variety in skills and knowledge of installers, as "*a low-carbon heat installer or engineer may (or may not) choose to become Microgeneration Certification Scheme accredited, join a Competent Person Scheme, or have a Building Control Body inspect their work*" (BEIS, 2018b, p.38).

Moreover, there were differing views as to who is responsible for raising awareness of heat pumps in the UK. The heat pump industry representatives said they have rather limited resources, and were suggesting that given the government's climate and energy targets, the government should put more effort into raising awareness of heat pumps, while others said that it was the responsibility of both the government and industry to raise awareness (UKExpert03; UKExpert04; UKExpert09). Many users mentioned for example EST as a source of information, but also government websites (especially Ofgem for the RHI), and manufacturers and installers websites. However, there is no one source where people could get independent information on the sector.

In terms of ***networks***, the UK heat pump sector is fragmented with several organisations promoting heat pumps, with the main ones being GSHPA, MCS, and HPA, who also co-operate. One expert identified the need to connect more with political actors:" *we've started investing in professional political lobbyists. We do a lot of lobbying ourselves on policy and we're very well-connected civil service level, but we weren't connected on a political level.*" (UKExpert03). Unlike in Finland, there does not seem to be one strong voice collecting everyone's views and providing a one common voice, or vision, for the sector. However, a representative from HPA acknowledged also their limited resources: "*I 'd like to think the Heat Pumps Association does pull a lot of that resource together, but I think we're just so very limited in what we can do, because of funding and representation.*" (UKExpert04). There are also other networks that advocate heat pumps, but these are usually focused on renewable energy in general rather than heat pumps specifically, and include for example community organisations and trade associations. Also, user-facilitated online networks are not as strong in the UK as they have been in Finland.

Heat pumps in the UK have faced a large amount of ***regime***-resistance. In addition to the lack of awareness of heat pumps, and the dominance of the cheap gas network (See Fig. 8), colloquially referred to as the "gas mafia" (Williams, 2012; see also Lowes et al., 2020), heat pumps have also had to compete against other niches, most notably solar power and biomass. For example, experts argued that the RHI had led to competition between different niche technologies, and that RHI subsidies and FIT had ruined the market for heat pumps as everyone chose solar and biomass over heat pumps and incentives run out for heat pumps (UKExpert03; UKExpert06). Heat pumps have had to compete also against incumbents in the oil and gas industry with one expert for example highlighting ministerial level lack of support: "W*e've met the Minister of State for Energy, Claire Perry. Again, okay, but if you're only looking at a fairly minority industry, it's, again, difficult to sort of really have an impact. I mean Claire Perry, for instance, was very, very concerned that if she backed heat pumps and was very anti-oil that a lot of her constituents who are actually on oil would be quite negative about that. Politicians look for vote winning opportunities*." (UKExpert04).

Our exploration of the second sub research question about the role of various user types for both niche construction and regime destabilisation confirms the importance of various user roles for both processes in the case of Finland. For the UK, we may speculate that the absence of active user involvement has hampered both niche construction and regime destabilisation.

Fig. 8. A preference for gas boilers has strengthened the regime of gas in the UK.
Source: Authors.

6.3. Explaining divergent developments

Results and arguments presented in Sections 5.1 and 5.2 clearly show that user activity is a necessary pivotal factor explaining the divergent transition trajectories between Finland and the UK. In the latter country we see a lack of user involvement, clearly a different situation as in former one. We argue that this passive attitude of users may be an important missing factor for a domestic heating transition in the UK. In Finland users have been very active, and without them the transition would have been much slower, resulting in persistent market uncertainties that manufacturers and installers may not have been able to solve just by themselves. Yet as we have concluded previously, two user roles, user-citizen and user-legitimator, did not come to fruition as strongly in Finland. Does this imply that the user-typology needs adjustment? Perhaps not all user-roles are critical for a transition?

To answer this question, we take as a starting point one of the suggestions by Kanger and Schot (2016) in arguing that user roles have specific functions relating to niche construction and destabilisation of regimes. For the former, user-intermediaries play a pivotal role, while for the latter, user-citizens are crucially important. User-citizens can play this outsider role by for example actively lobbying for a particular niche via social movements, bringing thus to the fore also the political nature of transition processes (e.g. Köhler et al., 2019). Accordingly, if the transition unfolds in a context of ongoing opening up of the regime, as was the case for Finland, this may well explain the lack of emergence of user-citizen and user-legitimator roles. After all, in Finland the old dominant domestic heating regime based on a combination of various heating sources, from oil, to wood and district heating, was relatively weak. Therefore, it had less problems of opening up to alternatives. This context was certainly not present in the UK where heat pump development faced direct competition from a much cheaper and vibrant gas fired heating regime.

We would like to look at the different transition contexts through the lens of the transition pathway typology introduced by Geels and Schot (2007) and discussed in Section 3.1. Based on this typology we can argue that in Finland the transition followed a de-alignment, re-alignment pathway in which regime destabilisation is less important, and thus the role of user-citizen and user-legitimator is less pivotal. In the UK, the heat pump transition faces a substitution scenario, for which it may need an articulation of all user roles, precisely to be able to open up the regime for change. In other words, what we have found is that the emergence and articulation of user roles is transition pathway dependent.

Kanger and Schot (2016) have argued that two user roles are specifically important for acceleration: user-intermediaries who play a pivotal role in the process of niche construction, expansion and embedding, and user-citizens who are crucially important for regime destabilisation. They thus question the assumption that regime destabilisation is often driven by economic drivers such as price and subsidies put in place by policy makers. These results resonate with Martínez (2017) and Turnheim and Geels (2012, 2013) who also argue that these drivers need to be put in place through an advocacy process, which is a specific form of institutional work (Fuenfschilling and Truffer, 2016). Based on a review of 23 energy and 11 transport transitions pre-1990, Martínez (2017, p.139), confirmed this by arguing that "*only those regime outsiders with both a radical (enough) ideology and influence over economic factors can destabilise the energy sector, which has strong incumbents*". The user typology by Schot et al. (2016) suggests that user-citizens forming or participating in a social movement can play this outsider role by for example actively lobbying for a change of the dominant regime. We want to qualify their statement by pointing out that this is the case in substitution pathway transition contexts. Accordingly, the hypothesis put forward by Schot et al. (2016) about the importance of all user roles in transition processes needs a substantial modification that provides a more nuanced role of users in various transition contexts: all the user roles are present throughout the transition process if it follows a substitution pathway.

7. Conclusion

We set out to examine the roles of users in two heat pump transitions, a successful one (Finland), and another less successful one (UK). Earlier studies of failed, or at least unsuccessful heat pump transitions like the one in the UK, have largely focused on analysing the role of policy in combination with structural conditions such as resources, the availability of certain energy infrastructure (e.g. gas networks), or climate in explaining how such transitions have developed.

However, as discussed in Section 2 (see also Table 1), when looking inductively and qualitatively at the reasons behind heat pump diffusion across Finland and the UK, both countries shared not only largely the same climatic conditions (cold winters, with a small growing need for cooling) given their geographic location in Northern Europe, but also an array of other socio-technical factors—cutting across infrastructure, markets, regulation, and research incentives. Our research shows that for explaining the major divergence between Finland and UK, we need to look into the substantial difference in user involvement. This is a necessary and key explanatory element. Finnish heat pump adoption was backed with strong user engagement and it is this factor alone that goes a long way towards explaining the successful diffusion of heat pumps contrasted with their continuing struggles in the UK. It is clear that in the UK, by comparison, heat pumps are facing direct competition from a much cheaper gas-fired heating, a regime resistance even likened by some interviewees as the "gas mafia" (see also Williams, 2012 and Lowes et al., 2020).

Our analysis implies that users in the UK may even become more important in the next phases of the transition in order to overcome this resistance. Since in the UK, the transition context is different, and thus may well need an articulation of various user roles, including the ones which were less important in Finland: the user-legitimator and user-citizens roles arguing and lobbying for a policy change. These user roles are important not only for pushing for policy development but also for policy implementation. For the latter, in Finland an actor such as SULPU fulfilled this role, which has been absent in the UK. This type of actor helps to develop social networks, and peer-to-peer sharing which can spread advice, and legitimize a new technology so that users become more familiar and comfortable with it.

Our research adds to the calls for policy-focused transitions research to pay more attention to other actors and their agency in transition processes (Kern et al., 2019). This is especially important as policies are not always fully able to reduce uncertainties for users, and can also be susceptible to political changes. The development of an active user base, performing a range of functions from user-producer, to user-legitimator, user-intermediary, user-citizen and user-consumer is perhaps a more stable predictor of a successful transition process. Users' role is not only salient in helping to start up transitions, and adopting new dominant solutions and integrating them into their lifestyles, but also in contributing to the acceleration process. Users therefore need to be involved in niche construction, as well as in regime destabilisation. The extent and mode of user involvement depends on the specific transition contexts, and in this study we have highlighted in particular how the heat pump niche in the UK has had to navigate competition from other niches, and more importantly, from strong regime resistance.

This emphasis on user involvement is not meant to be a substitute for policy. Instead we argue that users and policy form a recursive and interactive relationship. Policy makers and governmental actors should develop measures that complement user activities—like for example took place in Finland with government-affiliated Motiva playing a key part in the establishment of a heat pump association that evolved into a key user-intermediary. This indicates that policy could even be aimed at enabling and facilitating a rich community of user-producers, and the creation of strong user-intermediaries. In cases like the UK, where heat pump transition has failed to take off, this may be the way to unlock the current lock-in in the gas domestic heating regime. While policies, such as subsidies, together with improved awareness of heat pumps through education and training can help to reduce market uncertainties, they alone may not suffice. What is also necessary is a sustained and deep involvement of different user groups throughout the transition process.

Declaration of Competing Interest

The authors report no declarations of interest.

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Glossary

AAHP: Air-to-air Heat Pump
ASHP: Air Source Heat Pump
AWHP: Air-to-water Heat Pump
BEIS: Department for Business, Energy and Industrial Strategy (United Kingdom)
BSRIA: Consultancy firm (United Kingdom)
CAT: Centre for Alternative Technology (United Kingdom)
CCC: Committee on Climate Change (CCC) (United Kingdom)
DTI: Department of Trade and Industry (previous to BEIS in the United Kingdom)
EST: Energy Saving Trust (United Kingdom)
ExHP: Exhaust Air Heat Pump
FIT: Feed-in-tariff
GHG: Greenhouse gas
GSHP: Ground Source Heat Pump
GSHPA: Ground Source Heat Pump Association (United Kingdom)
Gt: Gigatonne
HPA: Heat Pump Association (United Kingdom)
IEA: International Energy Agency
IRENA: International Renewable Energy Agency
kW: kilowatt
kWh: kilowatt hour
LCBP: Low Carbon Building Programme (United Kingdom)
M&E: Mechanical and electrical systems
MCS: Microgeneration Certification Scheme (United Kingdom)
Motiva: Finnish Energy Efficiency Agency
Poratek: Finnish borewell association
RHI: Renewable Heat Incentive (United Kingdom)
SULPU: Suomen Lämpöpumppuyhdistys – The Finnish Heat Pump Association
UK: United Kingdom
VAT: Value added tax
WSHP: Water Source Heat Pumps