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Energy Internet forums as acceleration phase transition intermediaries

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ABSTRACT

Citizen users play important roles in the acceleration phase of energy transitions, during which small-scale renewable energy technologies (S-RET) become taken up more widely. From users' perspective, turning the early, and typically slow, proliferation into a more rapid and widespread diffusion requires not only the adoption of S-RET but also the adaptation, adjustment, intermediation and advocacy of S-RETs. These activities become necessary because S-RET face a variety of market, institutional, cultural and environmental conditions in different countries. New Internet-based energy communities have emerged and acted as key user-side transition intermediaries that catalyse these activities by qualifying market information, articulating demand and helping citizen users to reconfigure the standard technology to meet the specificities of different local contexts. In doing so, Internet communities foster an appreciatively critical discourse on technology. Such user intermediation is important in expanding the markets for S-RET beyond that of enthusiasts, environmentalists and other early adopters, to the early majority of adopters who demand more exposure, clearer information and less uncertainty about new technology options.

1. Introduction

The energy system is going through a transition towards an increased renewable energy generation. Many of the key renewable energy technologies – such as wind, solar photovoltaic (PV) and heat pumps – needed for the transition are already past the early start-up phase of transition, and are currently entering an acceleration phase where they begin to compete head-on with the incumbent fossil fuel-based technologies (Geels and Schot, 2007; Schot et al., 2016). In 2015, fuel share of renewables was 15% of global primary supply and renewable power capacity additions were over 160 GW, representing over half of global power generation growth (IEA, 2017a, 2017b). The growth rates and price reductions for key renewables continue to remain high, but they are only entering mainstream deployment and adoption in most markets (IEA, 2017a). In this situation consumers play an important part in the adoption and in the needed investments in small scale renewable energy technologies (S-RET), and consequently there has been a renewed interest in the roles that citizen users play in transitions, particularly after the early transition phases (Schot et al., 2016).

Research on the early phases of an energy transition has underscored the importance of citizen groups, such as community energy projects for example, working as activists and innovators, who initiatiate niche development in S-RET (Ornetzeder and Rohracher, 2006, 2013; Nielsen, 2016). In the later phases of a transition, citizen users have been found to be key players as adopters of the now better-developed technologies (Mignon and Bergek, 2016) and equally as intermediaries and advocates for the adoption of S-RET by other users and legitimators (Smith, 2012; Hyysalo et al., 2013b; Schot et al., 2016). Heiskanen et al. (2014), however, suggest that wide diffusion in a specific market may require a protracted period where market, technology and institutional characteristics continue to develop in parallel. As part of this, citizen users continue to adapt to, innovate, adjust, and advocate S-RET alongside adoption (Hyysalo et al., 2013a, 2016). All in all, a wider range of civil society roles may be played by citizens beyond the roles of consumers making choices and voicing preferences during the take-off and acceleration phases of transition (Smith, 2012; Durrant, 2014). Yet, the existing literature has only begun to address this wider casts of citizen user roles in specific transitions contexts and the range of community forms that are associated with it.

In this paper, we examine the activities that citizen users perform in an energy transition, particularly focusing on their functions as user-side innovation intermediaries (Stewart and Hyysalo, 2008). Our enquiry focuses on Internet forums dedicated to S-RET that have become major catalysts for user activities and networking. These Internet-based, peer-to-peer discussion forums (*Internet forums* from now on) present a new type of 'energy community', which points to the emergence of new types of relevant user communities in addition to previously identified community

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energy and other grassroots innovation communities that have been important in the early phases of energy transitions (Smith et al., 2014; Smith et al., 2016b; Ornetzeder and Rohracher, 2013). We examine the overall importance of the Internet forums in order to understand how citizen users, through peer-to-peer interactions, contribute to an energy transition after the early take-off phase. In doing so, we use transitions research framing, as it allows spelling out the full importance of the Internet communities for the proliferation of S-RET and its importance for sustainability transitions. This also allows linking a wide set of related empirical findings, which the otherwise relevant but more narrow research interests of grassroots innovation (Hargreaves et al., 2013; Martiskainen, 2017; Smith et al., 2016a), user innovation (Ornetzeder and Rohracher, 2006; Hyysalo et al., 2013a, 2013b, 2016) and user involvement (Heiskanen et al., 2010) literatures do not allow.[1] More specifically we focus on the following three interrelated questions:

1) What does a user perspective reveal of transition dynamics in specific country contexts?
2) What do users contribute to S-RETs diffusion at the acceleration phase of a transition?
3) How do peer interactions mediated by Internet forums act as user-side transition intermediaries?

Our paper proceeds as follows. In Section 2 we deepen the discussion on transition dynamics, user roles in transition, market formation for emerging technologies, and user communities. We then introduce our methods and data in Section 3. Section 4 presents our findings, first establishing the relevance of intermediation by citizen users in the Internet forums for S-RET proliferation and then moving on to examining the contents of their activities in depth. Discussion and conclusions (Section 5) elaborate further the functions served by citizen users in energy transition.

2. Sustainability transitions and user intermediaries

2.1. Sociotechnical regimes and transition dynamics

Research on sustainability transitions has developed during the last two decades to address the long-term change of sociotechnical systems. These systems feature high interdependencies between technologies, infrastructures, institutions, markets and everyday practices (Kemp et al., 1998; Kanger and Schot, 2016). Such systems or 'regimes' feature strong path dependencies and the vested interests of incumbent players further contribute to the inertia and resistance towards change (Geels and Schot, 2007; Geels et al., 2016). In this view, achieving a sociotechnical system transition is not only about better technological alternatives or market mechanisms but about gradual changes required in all aspects of the system – any one isolated change effort will only be partial and unlikely to succeed (Kemp et al., 1998; Schot et al., 2016).

Rotmans et al. (2001) differentiate four phases in the decades-long transition process – pre-development, take-off, acceleration and stabilisation. Schot et al. (2016) merge the earliest two phases into 'start-up phase', which is characterised by precarious early exploration and experimentation within 'niches' and relatively little interaction with, or impact on, the incumbent regime. Once the key new technologies and their institutional arrangements advance, they begin to challenge the incumbent regime, typically associated with a pressure for regime change from 'landscape' level. A contestation ensues between new and old technological, institutional, market and user practice arrangements (Geels and Schot, 2007; Geels et al., 2016). If the old regime does not manage to extinguish the new alternatives, the transition continues to the stabilisation phase where a new dynamic equilibrium is formed either through the incorporation of new elements into the regime, reconfiguration of new and old elements or substitution by a new regime (Geels and Schot, 2007; Geels et al., 2016). How these dynamics play out depends on at least the extent of lock-in and path dependence in the regime in question, actor choices in different regime contexts and cross-system interlinkages in the sociotechnical system. The ensuing transition consequently plays out in an uneven fashion spatially and temporally for different technologies in different contexts and countries (Lovio et al., 2011; Sovacool, 2016; Geels et al., 2016).

2.2. Citizen user roles in transition phases

With respect to users in these transition phases, Schot et al. (2016) and Kanger and Schot (2016) propose a schematised typology of important user roles in transitions. They suggest that user producers and user legitimators contribute to the available technological variety and discourse in the start-up phase (e.g. Ornetzeder and Rohracher, 2006, 2013; Smith, 2012: Smith et al., 2014; Nielsen, 2016). In the acceleration phase, the number of adopters grows and ordinary "user consumers" become important as their consumption choices make niche markets to expand. At the same time, some users tend to play intermediary roles that help other user consumers to adopt the new technologies and their usage. Such "user intermediaries" can have a profound effect on how easy it is for others to acquire, appropriate, learn and maintain the new technological alternatives (see Section 2.3.) (Stewart and Hyysalo, 2018; Hyysalo et al., 2013b; Kivimaa et al., under review). Users also affect the acceleration phase as active citizens by mobilising against the existing regime, hollowing out its legitimacy and commercial strength (Smith, 2012; Schot et al., 2016). The combined effect of these user roles facilitates the stabilisation of the new regime, which takes place at the moment when it has become more natural and routinised for consumers to make the choice in the new regime than in the old (Schot et al., 2016; Kanger and Schot, 2016). This recent focus on user roles in the transition literature thus moves it beyond its earlier reliance on the diffusion of innovation literature, which assumes that citizens merely adopt the novelty while some may act as diffusion champions that show examples to others and generate minor local reinnovations (Rogers, 2010; Mignon and Bergek, 2016).

Users' capacity to further the energy transition has been found to become amplified by peer interactions and communities. Research on community energy (e.g. Smith et al., 2014; Walker and Devine-Wright, 2008; Hargreaves et al., 2013) and energy-related citizen movements (e.g. Ornetzeder and Rohracher, 2006, 2013; Nielsen, 2016) has underscored how communities and movements create solutions that can be adopted into the mainstream, inflict change among dominant regime actors, and foster critical discourse and the practicing of technological and social alternatives (Smith et al., 2016b). Research to date has largely concentrated on community groups and movements that are united by an ideological commitment to alternative forms of energy and are often also geographically local (e.g. Kunze and Becker, 2015; Seyfang et al., 2014). Increasingly, community energy groups have also co-operated with each other, through shared learning and networking (Seyfang et al., 2014), often facilitated by national and regional intermediaries (Hargreaves et al., 2013). Such intermediaries include for example Community Energy England (Ehnert et al., 2017) and Community Power Scotland (Community Power Scotland, 2017) in the UK and Deutscher Genossenschafts- und Raiffeisenverband e. V. (DGRV) (German Cooperative and Raiffeisen Confederation) in Germany (Romero-Rubio and de Andrés Díaz, 2015). International platforms for cooperating are emerging, such as RESscoop umbrella organisation for cooperatives, bringing together a network of 1500 European cooperatives and their million citizen members (Alarcón Ferrari and Chartier, 2017). Research has also highlighted emerging sociotechnical concepts such as community microgrids, which could be used to integrate more S-RET in to the energy system, though their application remains limited (Gui et al., 2017). While in countries such as Denmark and Germany community-owned energy cooperatives have become a new type of an energy market player (Herbes et al., 2017), their influence remains limited in others (Smith et al., 2016b; Ruggiero et al., 2018). In all,

[1] We anchor our discussion on heat pumps in Finland, even though user forums covering S-RETs are present worldwide with varying intensity as detailed in Sections 3.2 and 4.1

community energy initiatives have been crucial community forms at the start-up phase of energy transition and they show signs of aggregated influence in the expansion phase of transitions.

Meanwhile, the acceleration phase appears to feature also other important citizen community forms and activities that go beyond physical communities and can potentially have even wider impacts on the transition (Heiskanen et al., 2014; Hyysalo et al., 2016; Heiskanen et al., 2017; Grabher and Ibert, 2014). Below we discuss how S-RET-specific Internet forums have grown into substantial catalysts for S-RET proliferation. For instance, the Finnish Internet forums that we examine feature over 500 000 posts between peers, have had over 200 million reads within a decade and have been accessed by over a third of the country's total population – a level of engagement that would be very difficult to achieve through largely localised, albeit collaborating, community energy projects.

2.3. Understanding user-side transition intermediaries

To better understand user communities and their mediating activities in the acceleration phase of transitions, new research designs are needed in transitions research agenda. Transitions framing should not be automatically seen as resulting in studies that take niches and regimes as the units of analysis, but to also include more detailed and micro-level studies that are positioned to transitions concepts. In the case of understanding users, user community forms and user intermediation, it makes sense to bridge transition research to STS and innovation studies that provide more detailed research and concepts for what users do. User communities – e.g. local communities, issue based digital communities, as well as user-developer communities of software and hardware – are known to be multifunctional spaces for their participants (Freeman, 2007; Grabher and Ibert, 2014; Johnson et al., 2010; Mozaffar, 2016; Smith et al., 2016a, 2016b; Verhaegh et al., 2016). Energy user communities appear not to be the grand exception to this rule, as users have and further a range of different motives, orientations, background competencies and participation pathways (Hyysalo et al., 2013b; Freeman, 2015; Grabher and Ibert, 2014). Through their activities and interactions, some users generate, accumulate and mediate knowledge on technology, market and user practices that would otherwise remain missing in the emerging market.

Such actors have been conceptualised as (user-side) innovation intermediaries. These are actors that mediate between the development and use of new technology, as well as actors involved in social and institutional innovation (Howells, 2006; Stewart and Hyysalo, 2008). These actors may influence, but cannot fully control, the design or use of the technology or innovation outcomes more broadly, which sets them apart from other actors that are more aptly described as either just suppliers or users of technology (Stewart and Hyysalo, 2008). While early research on intermediaries focused on the typically more visible supply side intermediaries, such as knowledge-intensive business services, it has become gradually understood that there are equally important activities that intermediaries play on the user side. Peers or third parties have been found to act for instance as local experts (Stewart, 2003; Bakardjieva, 2005) or tailors and configurers (Okamura et al., 1994; Barnes, 2016). Such user-side intermediaries are involved in *configuring* technologies, users and spaces for technology appropriation, *facilitating* the uptake of new technologies and *brokering* connections and transactions between the other actors involved (Stewart and Hyysalo, 2008; Barnes, 2016). Following Kivimaa et al. (under review), transition intermediaries can be regarded as those innovation intermediaries that mediate within a sector (such as energy) or a region (such as a country) towards a systemically new and more sustainable configuration.

Citizen users' peer interactions thus offer a view as to what user-side transition intermediaries are and what they do – a topic which has remained in the shadows of the otherwise prolific literature on intermediaries in sustainability transitions (Martiskainen and Kivimaa, 2017; Kivimaa et al., under review). Indeed, more research is needed both on the kinds of *activities* that such user-side innovation intermediaries support, and what *functions* these play in the context of the acceleration phase of sustainability transitions.[2] To understand these activities requires an in-depth study of usages, procedures, technologies and knowledge constructed and shared inside the community (cf. Grabher and Ibert 2014), and this is what we shall outline next before moving into detailed empirical examination of Internet forums dedicated to S-RET.

3. Methods and data

We draw together results from a six-year research programme conducted during 2011–2017 on user roles in S-RET innovation and diffusion in Finland (Hyysalo et al., 2013a, 2013b, 2016; Freeman, 2015; Heiskanen et al., 2014). The research design follows the biographies of artifacts and practices approach within STS, which combines ethnographic study, in the current case through virtual ethnography of the Internet forums supported by semi-structured interviews, with diachronic study of how the focal technology and user practices, markets and infrastructures related to it have evolved over time (Hyysalo, 2010; Hyysalo et al. under review). This approach builds a gradually deepening line of enquiry into the interlinked settings and times where the focal technology and user practices have been shaped (Pollock and Williams, 2008; Hyysalo, 2010; Hyysalo and Usenyuk, 2015). The approach entails taking a mixed-methods approach and in our case using both qualitative and quantitative data-sets to understand how citizens as consumers and users engaged with S-RET in Finland from 2000 to 2013 (in this paper focusing on air-source heat pumps [ASHP] and ground-source heat pumps [GSHP]).

3.1. The context of the research

Finland presents a good case in which to study acceleration-phase intermediation regarding heat pumps. On a per-capita basis it has one of the largest number of heat pumps sold annually (Heiskanen et al., 2014, p. 176), the acceleration has happened in the current millennium and corresponded with the availability of new forms of digital platforms (see Section 4.2). The housing stock and ownership structures in Finland are well-suited for the installation of heat pumps. The country is a home-owner society (71% of the population own their home (Tilastokeskus, 2017a)) and detached houses are common (counting 65% of housing stock) (Tilastokeskus, 2017b). Even though energy prices in Finland are among the lowest in the European Union (EU), and average incomes are high, cold annual average temperatures (6 °C in the south of Finland) add to overall heating bills. Heat pump adoption has been only modestly advanced also by a mix of policies, which have addressed energy efficiency and renewable energy use in the residential sector, including subsidies for replacing oil-based heating systems (Kern et al., 2017).

Regarding peer support over Internet, Finland has a large number of Internet users (UNDP, 2016), and it forms a specific 6 million people language area, which may contribute to citizens' willingness to engage in specific online communication forums. The first S-RETs Internet discussion forum for GSHPs emerged in 2004 (www.maalampofoorumi.fi), and the second for all heat pumps in 2006 (www.lampopumput.

[2] There is ambiguity in the research literature regarding the conceptual registers between what 'functions', 'roles', 'activities' or 'tasks' intermediaries perform, authors often hovering between undifferentiated uses of these terms. Hakkarainen and Hyysalo (2016) critique the (often ever growing) lists of *what* intermediating actors say they have been involved in mediating (as answers to e.g. a survey). When more detailed data is available it makes sense to characterise *how* they have done it i.e. the doings of intermediaries as concrete 'tasks' and more persistent 'activities', rather than relatively unspecific role-lists (Hakkarainen and Hyysalo, 2016). As some intermediaries perform their activities informally and aside to their main activities, to describe them as serving 'functions' is to potentially impose a kind of system-level self-awareness and planfulness to their actions that might exist for organisations established to intermediate (e.g. governmental affiliated agencies and industry associations, Kivimaa, 2014) but not, for instance, in peers helping others as 'local experts' (Stewart, 2003; Stewart and Hyysalo, 2008). The vocabulary of functions is however useful in providing an outsider perspective on the *effects* of the intermediary on the transition process and is in this paper reserved for this use.

info). These were followed by a forum for wood burning systems in 2007 (www.pellettikeskustelu.net) and for 'free energy' (www.ilmaisenergia.info) in 2009, to which micro-wind, solar heat and solar PV became clustered to. Over the years these have evolved into a major communication medium amongst the citizen users of these energy technologies. By the end of 2016, the largest of the heat pump forums alone (www.lampopumput.info) had been viewed 150 million times in its eleven years of existence. These are not Facebook groups or general online message boards such as those found in AOL or Suomi24 (Finland24) but moderated, categorised and accumulative repositories. Such forums exist worldwide for software and hardware technical support and for consumer exchanges on a variety of goods, such as bicycles or cars. The discussions are typically anchored to specific problems with specific technologies: their features, makes and models, as well as some typical usages and activities associated with those technologies. Such fora proliferated rapidly after 2001, when easy-to-use free Internet forum software platforms became available for anyone to set up a public online discussion forum. Heat-pump related Internet forums in many other countries are of similar magnitudes.[3]

3.2. Data collection and analysis

Our collection and analysis of data related to the Internet forums has included several steps, as outlined below:

To gain an overview of the diffusion of heat pumps in Finland and its relation to the development of Internet forums we first obtained the *national sales statistics* from the Finnish heat pump industry association (SULPU) on all heat pump types since the 1980s, complemented by analyses of heat pumps in Finland during 1980–2000 by Heiskanen et al. (2014), Heiskanen et al. (2017) and Lauttamäki (2018). We then obtained *statistics on all the major heat pump Internet forums* (see Section 3.1 above). As detailed statistical coverage for the whole duration of a forum's lifespan only exists for the largest of the forums, lampopumput.info, we use this forum as the focus of our analysis. These statistics cover postings, topics, readings, unique IP addresses, registered members, member posting profile distributions and readings per discussion area.

To understand more deeply how the Internet forums functioned, we examined *Internet forum membership, postings and contents*. First, we examined how new page views, members and postings have accumulated in the lifespan of the forums (see Fig. 1), and then complemented this overview characterisation by content analyses performed as part of our altogether 13 person months *Internet ethnography* (conducted in 2011–2012 and 2017). The ethnography included the base-level characterisation of the contents of the forums' main subsections, consisting of a detailed coverage of 5–20 discussion threads per category, and analysis of how members had sectioned and categorised the forums. These helped to establish which forum areas (the categories for posts) had significant amounts of posts and how uniform the postings in each area were regarding form and content. In categories where more variety was found, we went through up to 20 threads in detail in order to understand the variety in contents and interaction activities. In categories which featured low variance in content and form we settled on 5–10 threads (Gobo, 2007). Next, we covered those forum sections entirely that were particularly variable and of interest to us – such as 1206 discussion threads on 'modifications and improvements' in 2012. Our research included an analysis of innovations by citizen users in Finland, altogether consisting of 213 verified user innovations in S-RET, 113 of those dealing with heat pumps (Hyysalo et al., 2013a, 2013b, 2016).

The ethnography included also 61 semi-structured interviews to gain personal accounts from the *Internet forum users and their activities*. Of these, 47 were with forum-active inventive consumers, five (5) with firms that had collaborated with inventive consumers and nine (9) with users who had only adopted the S-RET technologies. Each interview was recorded and lasted for 30–120 min. We also manually examined the full user profiles of 115 forum users regarding posting types, post contents, how long they had been active and how active they had been in the forums.

The above data was complemented by an analysis of one locality bound heat pump project in 2007 when heat pump proliferation was early stages in Finland (see Martiskainen, 2014). A total of seven (7) interviews were conducted, four (4) with users and three (3) with intermediaries involved in the project. These interviews lasted between 60 and 120 min each. They were recorded and thematically analysed to illustrate the challenges and barriers early adopters of heat pumps in Finland faced (Section 4.1).

The posts and interviews were coded by 1–3 researchers. The initial coding focused on usage, procedures, and technology and design knowledge, which was constructed and shared inside the community (cf. Grabher and Ibert 2014). For usage, we analysed practices related to heating equipment (for example advice of purchasing, installation, daily use, maintenance, general instructions, problem solving, second hand sales and repurchasing). Procedural codes focused on forum activities and discussions around laws, status and building open source community. Technology and design related coding analysed the nature and make up of inventions, types of technology featured in the forums, support given and received, and members' learning and development pathways. In the second stage of analysis these first level thematic codes were clustered under major themes relating to user roles in transition, followed by presentational coding and the resulting presentational narrative in Section 4.1.

4. Empirical findings: heat-pump diffusion and internet forums in Finland

4.1. A consumer perspective on the early acceleration phase of S-RET diffusion: a microcosm of themes

We begin to highlight the issues involved in S-RET adoption through a case, which portrays well the difficulties and time consumers had to expend to make an informed choice about heat pumps in 2007. This was at a time when heat pump technology had already reached 13% of its estimated maximal diffusion in Finland and was thus past its very earliest stages of proliferation (see Fig. 1). This case presents a microcosm of the types of information and advice that peer advice in the Internet forums accomplished soon after, rendering easier consumer decisions.

During 2007–2008, members of a Finnish residential association in a small town of Valkeakoski ran a project to gain independent information on ASHP and GSHP technologies, which they had first encountered in a Finnish Housing Fair (Heiskanen et al., 2011; Martiskainen, 2014). The technology seemed like a good fit to their residential area, where most houses had electric heating without water-based radiator systems, yet all the information available at the housing fair was limited to advertisements.

Despite frequent mentions in Finnish media at the time, the two project champions had to conclude that "*there just was no reliable, comparative information available from anywhere*" (Martiskainen, 2014, p.183) and that "*everyone was trying to find that information by themselves and potentially duplicating that work so we thought that this could be an issue that may have wider interest … in our area*" (Martiskainen, 2014, p.183). The men then proceeded to run a project within the residents' association to find out more about heat pump models and ensure better success in bidding and instalments as "*there ha[d] been some cowboys on the installation side … [and] a lone person is more at the mercy of sellers*" (Martiskainen, 2014, p.186).

The duo then contacted approximately 20 organisations in order to find an expert to help them. These included a local vocational school;

[3] For comparison, Sweden's Varmepumpsforum focuses solely on heat pumps and was established in 2004; it has over 40 000 registered users and has had over 660 000 messages posted on it. In Germany, (www.haustechnikdialog.de/Forum/30/Waermepumpen) the largest forum has attracted active discussion with almost 20 000 topics, i.e. of the same size as the largest Finnish forum. In Norway, the discussion has been scattered around different Internet sites. Some of the sites include thousands of topics concerning different heat pump technologies, e.g. http://byggebolig.no. In North America, several home improvement, repair and DIY websites cater for heat pump discussions with a rather limited number of message threads.

the Finnish Heat Pump Trade Association; a building trade magazine; a regional Heating, Ventilation and Air Conditioning Association; a government energy efficiency agency; Agrifood Research Centre Finland; the National Work Efficiency Institute; and the Technical Research Centre of Finland. The men expected all of these organisations to have expertise in heat pumps. Apart from a lecturer from the local vocational school and the regional Heating, Ventilation and Air Conditioning Association, these organisations were not willing or able to get involved or offer technical expertise. The duo concluded that "*small-scale generation is not valued in Finland. The consumer does not know enough and does not get help or information … we really tried hard to find that expert help*". (Martiskainen, 2014, p.195).

Undeterred, the men applied for EU regional funding to run a nine-month €16k project comparing 82 heat pump models for a potential joint purchase. This culminated in a public event where the project results were discussed and freely shared, and at which 12 heat pump vendors were present (others had been contacted but they did not attend).

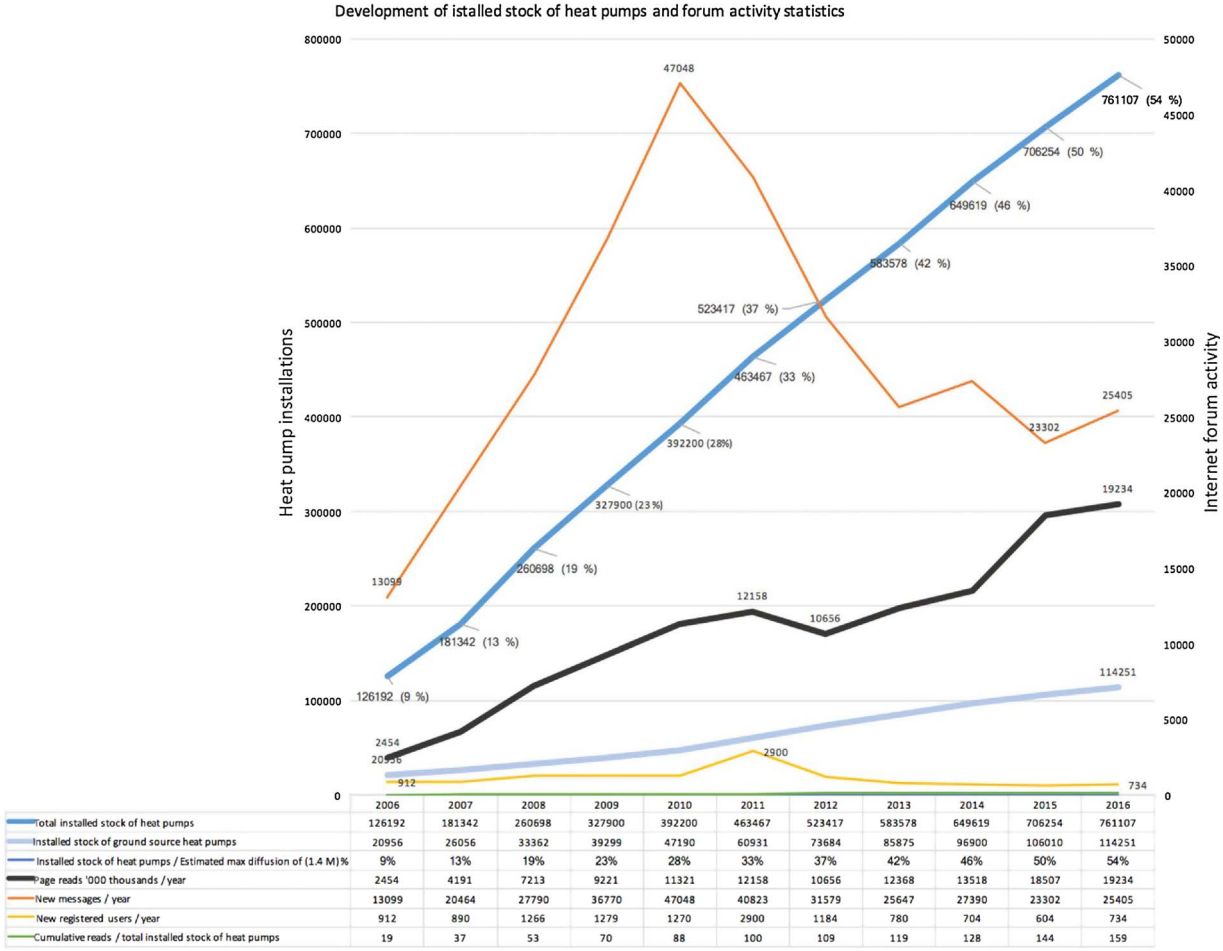
> *"We were completely taken aback by the sheer number of people that came. We had expected around maximum of 150 people to attend and we had close to 700 on the day".* (Martiskainen, 2014, p.200)

The successful event led to the joint purchase of 120 heat pumps, which at best resulted in the recouping of investment in less than two years through reduced energy bills. Afterwards, the residential association was contacted by the government's energy efficiency agency to build information packages on heat pumps, but the market was developing fast and the association's information had already become outdated (Martiskainen, 2014).

This empirical example illustrates, first, the poorly developed state of the market at the point when approximately 13% diffusion in the specific national market existed, together with a rather lucrative payback time and already high international production volumes of this S-RET. Secondly, we see how the underdeveloped market institutions were being surpassed by considerable labour by consumers, through making contact with a range of intermediary actors that could have potentially mediated new S-RET with consumers, but which, in fact, only mediated an aspect of heat pump technology that was not sufficient or suited for consumers. Thirdly, we notice how the local activities served the local community but quickly became obsolete for upscaling the needed information in the rapidly evolving market. Finally, we see one of the last unconnected citizen initiatives for making an informed choice about heat pumps in Finland. At the time this project was running, other citizens had set up Internet forums to aide fellow citizens in scaling, selecting, installing, maintaining and improving this technology that soon connected most citizen initiatives in the country.

4.2. Internet discussion forums dedicated to S-RET and their growth patterns

The Internet fora can help the above types of consumer problems encountered in the context of the acceleration phase. The first for S-RET were set up by citizen users after the first few thousands of people had adopted the technology in Finland, between 2004 and 2008. The growth of installed heat pump stock and forum reads has then been



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total installed stock of heat pumps	126192	181342	260698	327900	392200	463467	523417	583578	649619	706254	761107
Installed stock of ground source heat pumps	20956	26056	33362	39299	47190	60931	73684	85875	96900	106010	114251
Installed stock of heat pumps / Estimated max diffusion of (1.4 M)%	9%	13%	19%	23%	28%	33%	37%	42%	46%	50%	54%
Page reads '000 thousands / year	2454	4191	7213	9221	11321	12158	10656	12368	13518	18507	19234
New messages / year	13099	20464	27790	36770	47048	40823	31579	25647	27390	23302	25405
New registered users / year	912	890	1266	1279	1270	2900	1184	780	704	604	734
Cumulative reads / total installed stock of heat pumps	19	37	53	70	88	100	109	119	128	144	159

Fig. 1. Cumulative installations and user activity development in the main forum for heat pumps in Finland.

roughly linear, with reads growing at a faster pace[4] (see Fig. 1, bolded lines), so that the year 2006 had 19 reads per pump while by the year 2016 this had increased to 159 per pump (see Fig. 1). As is common to such digital sites (Grabher and Ibert, 2010), readership has been much more numerous than registering and posting questions or comments: for lampopumput.info the cumulative reader count exceeded 2.5 million by 2017, indicating that 1–3 million visitors visited the forum in a language area of 6 million people.[5]

Interestingly, the numbers of new posts and new registered users peaked during the years 2009–2011 (400 000 installed systems or 30% of estimated max diffusion) and then gradually decreased to roughly original annual levels, eventually 5500 people, i.e. 0.1–0.5% of readership registering. There are several simultaneous explanations for these changes. By this time, the accumulation of knowledge in the forums became sufficient for an increasing number of new users so that fewer people needed to register and post questions in order to satisfy their information needs in acquiring and maintaining heat pumps. At the same time, the market developed so that merely acquainting oneself with the basics of scaling and selecting a heat pump became sufficient prior to purchase for most users. The later adopters may have also been less interested in details of their purchases, as diffusion theory would suggest (Rogers, 2010). Yet, as the number of messages increased over the years, more pages became available for any given topic and users had more content they could read per query. The forums have also simultaneously served users contemplating the purchase of a heat pump, and those who already owned a heat pump and needed to troubleshoot or improve it.

Overall, activities in forums rose from the estimated 10% diffusion to 30% diffusion. After these new memberships, new postings and new topics slowed down associated with accumulation of information and maturing of the market (Fig. 1). But to understand why and how the information accumulation and market maturation happened, we need to examine the contents and interactions at the forums in more detail.

4.3. User forums as intermediaries in S-RET market formation

We thus next dive deeper into the activities, interactions and contents at the Internet fora. We begin in this Section by examining the roles these play in market formation and then shift to examining their yield in adjusting the technology to the specific country context (Section 4.4). Regarding market formation, the fora provide contextual and qualifying information that other actors in the emerging markets do not or cannot provide (Section 4.3.1), and how this leads consumers to direct other actors in the market (Section 4.3.2). The accumulating user data from different settings allows the fora to demonstrate what is the realised value of new S-RET and thus to countenance inflated or deflated claims about the technology (Section 4.3.3).

4.3.1. Providing the qualifying information that is missing among the market mechanisms

As our opening case and the high demand for information in heat pump forums illustrate, new institutions and organisations that make new commodities exchangeable in a market (Kopytoff, 1986; Green, 1993; Callon et al., 2002; Pollock and Williams, 2016) may not readily exist, and other actors end up serving the needed development and market functions (Howells, 2006; Stewart and Hyysalo, 2008). We examine in detail a key ‘entry post’ on ASHPs from 2007 (Fig. 2) as many of the forum discussion threads provide a ‘Read this first’ section containing basic information on which discussion each relevant thread focuses on.

Fig. 2 shows a condensation of much of the knowledge (and meta-knowledge) that the Valkeakoski project recounted in Section 4.1 took months to establish. The first five bullets deal with technical issues and introduce the relevant terminology: what solutions can be regarded as up to date and what are the threshold values for typical concerns such as noise level? These are followed by three bullets for the Finnish national context: how to scale the heat pump for different winter temperatures. The most important issues are set in bold to link to other posts that provide more information at the forum. The lowest four bullets proceed to instruct the user on how to navigate vendor-provided information.

Resulting in 40 000 reads, this posting and many of its kind go some distance in helping potential buyers to approximate what they need to know to make a sensible heat-pump acquisition, including:

- *The space required for heating*. Does the user want to heat a house, garage, outbuilding or cottage for example? What is the size and type of the heated space (e.g. a detached, semi-detached or terraced house) and the number of floors and the number of rooms? Can the user provide a floor plan? These questions prompt to gain clarity about the points that follow.
- *Energy profile and behaviour*. How much energy and hot water does the user consume and from which sources (e.g. electricity or other sources)? How much does this consumption cost annually?
- *Current and future heating system*. What type of a heating system will the user have in place, e.g. does the user want to replace an existing heating system or combine it with a heat pump (examples include electric heating, oil-based heating, wood-based heating)?
- *Heating controls*. Would the user like a heat pump that can be controlled remotely? Does the user mind repetitive behaviours, such as turning radiators up and down, or would s/he rather leave heating controls untouched for the majority of the time?
- *Personal preferences on noise and aesthetics*. Has the user thought about the potential noise and aesthetics implications of the heat pump (i.e. what will the heat pump sound and look like post-installation)?
- *Actual local weather conditions*. These are important, particularly during winter, as they affect the choice of a heat pump considerably.

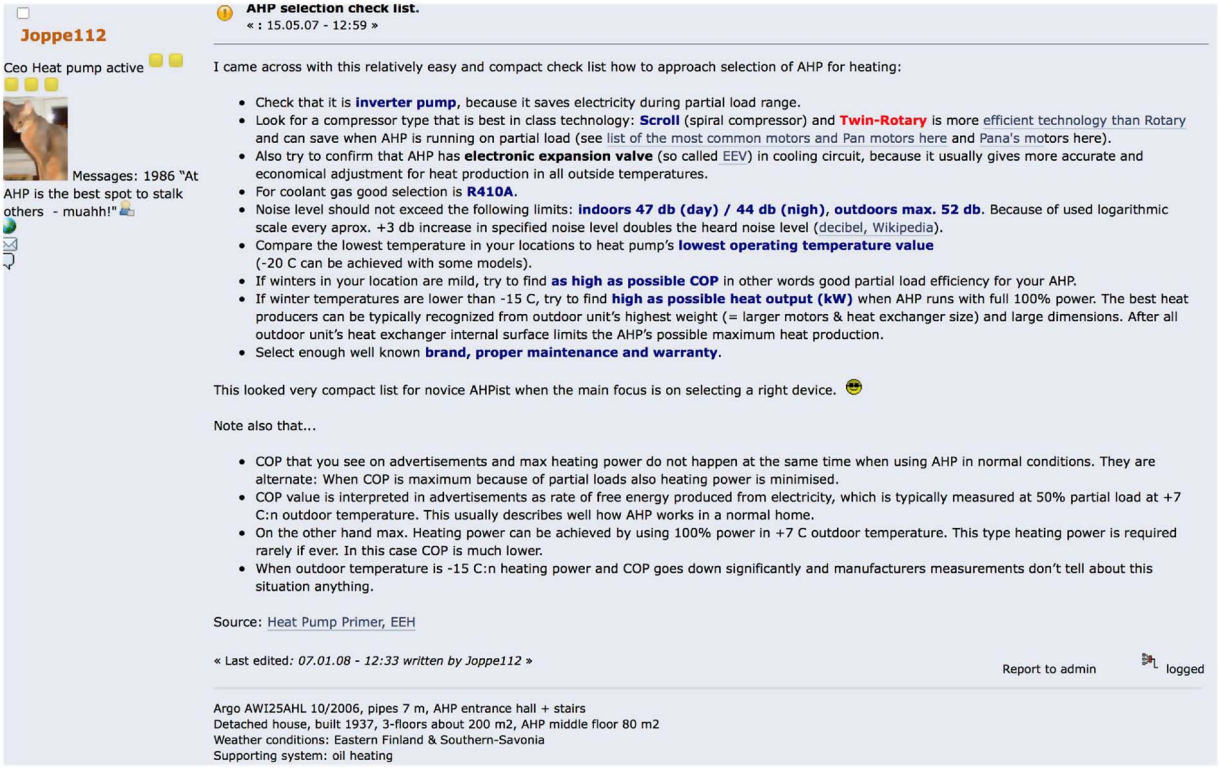
Guiding prospective users to these parameters is paired with instructions, calculators and long threads related to each of these key topics. For instance, with respect to local weather conditions, winter temperatures are linked to 1) energy consumption data in different locations gained from the country’s technical research centre and 2) each particular heat pump make, model and its measured performance (through 14 tables and charts). This produces a set of charts for an interested user to fit to his or her location and heating needs: an arguably useful exercise as the ideal yield varies between 24% and 40%. The citizen user is further guided on how to calculate the optimal investment in a heat pump if an oil-based heating system is also retained.[6]

The forums thus produce a suggestive image of what it means to be an *informed consumer* and the nature of the *information to be consumed*. In the wording of Stewart, they pre-configure the user along the relevance of technical characteristics (Stewart, 2003; Stewart and Hyysalo, 2008). These postings typify further common intermediary activity which users perform to help their peers: rather than producing new-to-the-world information, users collect, condense, integrate and explain information produced by other parties. They further configure the information to the national market specifics, making it directly

[4] One should add 20–30% more reads in the GSHP forum in order to get the full picture regarding heat pumps.

[5] The cumulative reader count is measured from unique IP addresses. The IP addresses from an organisation can show as only single address but also people can have several IP addresses from which they access the site. The rules of thumb for counting real visitors from IP addresses vary, typically so that there are more visitors than IP addresses, but given the decade-long timespan here, we use a conservative and broad estimate of 1–3 million visitors.

[6] See the full discussion at http://lampopumput.info/foorumi/index.php?topic=1375.0



AHP selection check list.
« : 15.05.07 - 12:59 »

Joppe112

Ceo Heat pump active

Messages: 1986 "At AHP is the best spot to stalk others - muahh!"

I came across with this relatively easy and compact check list how to approach selection of AHP for heating:

- Check that it is **inverter pump**, because it saves electricity during partial load range.
- Look for a compressor type that is best in class technology: **Scroll** (spiral compressor) and **Twin-Rotary** is more efficient technology than Rotary and can save when AHP is running on partial load (see list of the most common motors and Pan motors here and Pana's motors here).
- Also try to confirm that AHP has **electronic expansion valve** (so called EEV) in cooling circuit, because it usually gives more accurate and economical adjustment for heat production in all outside temperatures.
- For coolant gas good selection is **R410A**.
- Noise level should not exceed the following limits: **indoors 47 db (day) / 44 db (nigh), outdoors max. 52 db**. Because of used logarithmic scale every aprox. +3 db increase in specified noise level doubles the heard noise level (decibel, Wikipedia).
- Compare the lowest temperature in your locations to heat pump's **lowest operating temperature value** (-20 C can be achieved with some models).
- If winters in your location are mild, try to find **as high as possible COP** in other words good partial load efficiency for your AHP.
- If winter temperatures are lower than -15 C, try to find **high as possible heat output (kW)** when AHP runs with full 100% power. The best heat producers can be typically recognized from outdoor unit's highest weight (= larger motors & heat exchanger size) and large dimensions. After all outdoor unit's heat exchanger internal surface limits the AHP's possible maximum heat production.
- Select enough well known **brand, proper maintenance and warranty**.

This looked very compact list for novice AHPist when the main focus is on selecting a right device.

Note also that...

- COP that you see on advertisements and max heating power do not happen at the same time when using AHP in normal conditions. They are alternate: When COP is maximum because of partial loads also heating power is minimised.
- COP value is interpreted in advertisements as rate of free energy produced from electricity, which is typically measured at 50% partial load at +7 C:n outdoor temperature. This usually describes well how AHP works in a normal home.
- On the other hand max. Heating power can be achieved by using 100% power in +7 C outdoor temperature. This type heating power is required rarely if ever. In this case COP is much lower.
- When outdoor temperature is -15 C:n heating power and COP goes down significantly and manufacturers measurements don't tell about this situation anything.

Source: Heat Pump Primer, EEH

« Last edited: *07.01.08 - 12:33 written by Joppe112* »

Report to admin logged

Argo AWI25AHL 10/2006, pipes 7 m, AHP entrance hall + stairs
Detached house, built 1937, 3-floors about 200 m2, AHP middle floor 80 m2
Weather conditions: Eastern Finland & Southern-Savonia
Supporting system: oil heating

Fig. 2. An entry post for guiding ASHP selection (text translated from Finnish).

relevant and reducing scientific and professional content that is not directly relevant for fellow citizens. Such bricolaging, aggregating, editing and opening topics for peer commentary and validation are typical activities of peers which greatly facilitates other users even though peers do not physically configure each other's energy equipment.

4.3.2. Directing other actors in the market: acting as a back channel against commercial claims and service

The forum discussions are not limited to meta-knowledge but also include a proactive and reactive direct influencing of commercial actors. Regarding reactive measures, each heat pump make and model has come to have a specific section on the forum where users relate their experiences and suggestions, sometimes paired with resellers seeking to assert their views as well. The same goes for pump installation and maintenance, which effectively produces a community memory and public complaint channel in cases of failures (by e.g. the feared 'cowboy installers' who can ruin the installation or worse, damage the house). Together with actions by the national industry association SULPU, the citizen forums have helped to keep the rapidly evolving market in check and to maintain its reputation among the wider public.

Proactively, the available options in the choice of manufacturer, heat pump type and model, and issues such as costs, installation and maintenance are rendered accessible by the forums. The forums relativise manufacturers' brochures and adverts, and countenance exaggerated claims, stressing reliable brands with aftercare and warranties. They provide guidance on installation, for instance where the heat pump is best located in terms of airflow, pipeworks, fireplaces and aesthetics. As an illustration, one discussion on the best place for an internal heat pump unit comprises 24 pages of commentary, based on the actual floor plans posted by the users. These proactive and reactive peer activities are paired with a 'Hot Ring', where controversial topics and debates are moved to in order to keep the forum reliable without overblown censorship. When forum popularity arose, these measures began to police the market actors.

4.3.3. Providing evidence of realised value and counter evidence against claims of poor S-RETs performance

Many forum discussants monitor the real-time performance of their equipment and post these performance curves for others to see, with some providing very detailed calculators for estimating the likely performance in real conditions. These activities are augmented by make- and model-specific advice given for how to gain yield information and, if necessary, how to rig one's heat pump to achieve it. As most forum participants provide their location, house specifics and equipment configuration in their signature field, the monitoring activities aggregate a repository of real-life measurements of heat pumps across different settings, and outdoor and indoor temperatures, which allows for comparisons (Fig. 3).

The primary purpose of these activities has been to go beyond the manufacturer-provided information that has been tested in the standard test conditions (typically the above-noted +7 °C) for which the equipment is optimised (as all devices are) and spot inaccuracies and errors in manufacturers' data. The secondary intermediary function of the monitoring activities has become, however, the capacity to also countenance the results, and study the set-ups and calculations of other parties, such as research institutes, whose studies are actively and critically discussed in a specific section of the forum.

4.4. Re-contextualising the standard technology to national specifics

4.4.1. Learning about new technology and its use

The traditional view of diffusion has been one of a roll out and adoption of an unchanging good, but It has by now become widely accepted that many diffusion processes include 'reinnovation' at local sites (Rogers, 2010). Innovation studies have further drawn attention to the various feedback loops back to producers, which lead to improvement of the general technology during the diffusion phase in order to meet local needs. Such process has been characterised as 'innofusion'; we first examine its local component in learning about new technology and its use in specific contexts (Section 4.1.1) and then the changes

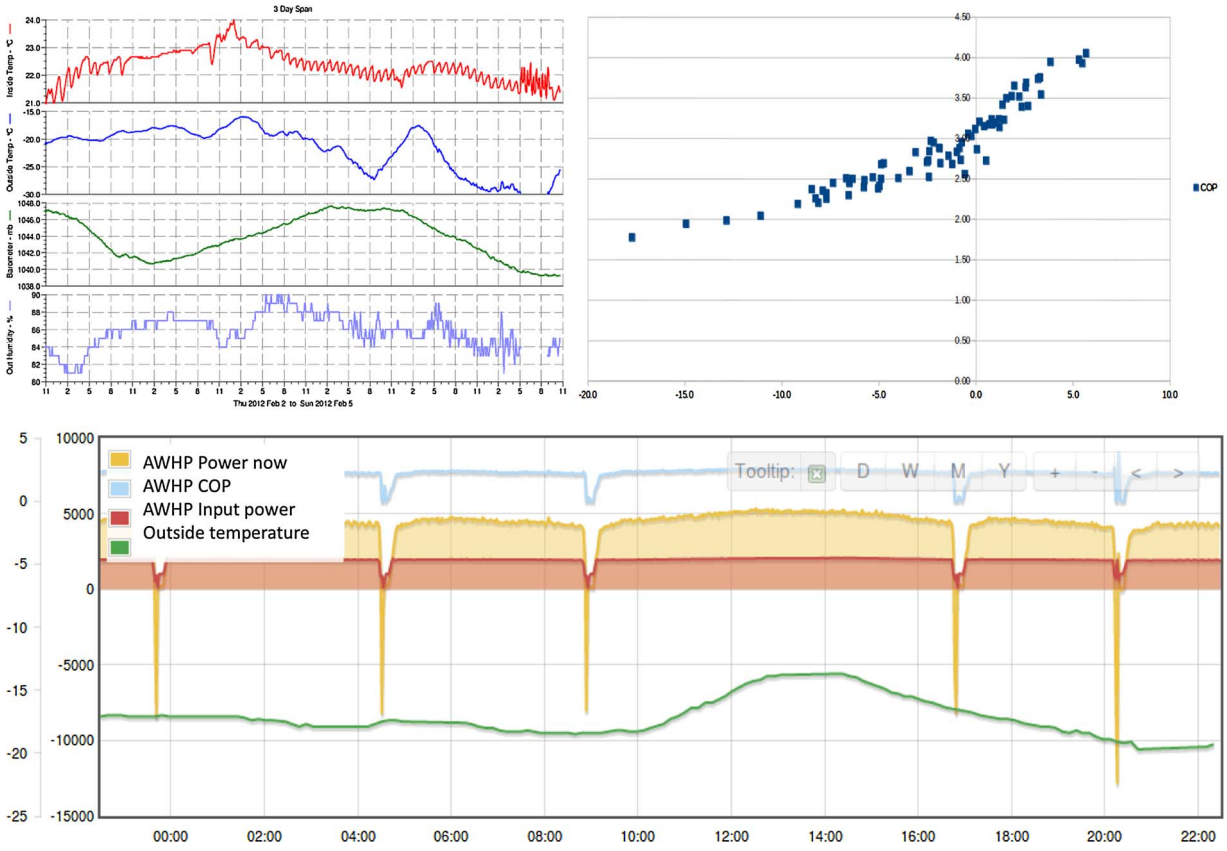


Fig. 3. User-created measurement graphs illustrating ASHP performances in different temperatures.

these have contributed to in technology development (Section 4.4.2) (Fleck, 1993; Heiskanen et al., 2014; Hyysalo and Usenyuk, 2015).

By the time ASHPs entered Finland their global installation numbers were in the millions, though their major applications were in cooling and heating in more moderate climates. Learning to select, install, maintain and troubleshoot heat pumps in the new, colder market received considerable attention from citizen users in the Finnish Internet forums. The country-specific particularities of houses and climate combined meant that installers and users could not take manufacturers' instructions for granted, and Internet forums consequently came to compile information on:

- Installation problems and how to prevent them (see Section 4.3)
- Troubleshooting and compiling information about typical cold climate problems and solutions, such as icing, cleaning, drafts, too high electricity consumption etc. (Fig. 4, left hand side)
- Monitoring performance in and between different makes and models in different temperatures, particularly in cold conditions and specific locations
- Improving everyday performance and sharing small reinnovations, such as how to easily remove ice from underneath an ASHP outdoor unit (Fig. 4, middle) and how to best fit the heat pumps to existing housing stock (Fig. 4, right)
- Improving performance in special conditions, such as summer houses, warehouses or garages. For example, there is a need to set up low base temperature to maintain summer houses over long winter absences, which can be achieved by adding a resistor to ASHP to make it maintain 8 °C temperature instead of standard minimum of 16 °C to lower energy consumption.
- More encompassing user innovations, 113 in total, in improving the yield and suitability of heat pumps. An example includes combining ground circuit outdoor unit with air heating indoor unit to create model suited for coldest climate zone houses without water circulation central heating, which standard GSHP would require (Hyysalo et al., 2013a, 2016).

These alterations to the technical make up and usage patterns of the heat-pump technology contributed to gradual improvement of the producer offerings, which we will examine next.

4.4.2. *Contributing to demand articulation and technical improvement*

The citizen users and their discussions in Internet forums further contributed to direct and indirect demand articulation for further development of heat pumps for cold climate markets. In the beginning of diffusion, some users advocated cheap heat pumps over the expensive early cold temperature models. At the end of the study period, the colder temperature models have become the norm and most advanced ASHP retained positive COP at −25 °C (instead of −15C, typical to the beginning of the study period). There have been several combined mechanisms at play in the significant advances to these cold temperature-specific models. On the one hand, the over hundred different innovations by users on heat pumps have introduced solutions, some of which have later appeared in producer models and most of which have been discussed and thus signalled at the forums for resellers and manufacturers (Hyysalo et al., 2016). On the other hand, large sections of forums devoted to discussions on winter performance signalled to the importers and manufacturers that ASHP use in cold temperature called for improvement, and with the growth of the cold-temperature market this sent a signal to manufacturers to improve their cold-temperature models.

Another important development in demand articulation has been that citizen users began operating heat pumps along other heating technologies. Whereas vendors and energy experts initially assumed that people would replace whatever heating they had with heat pumps, it became common to purchase an ASHP in order to complement existing heating systems based on oil or solid wood, as well as to also

Fig. 4. Examples of heat pump installations and user modifications.

complement AWSHP and GSHP with solar thermal collectors. The resulting 'hybrid heating systems' utilised the best yield time of each heating source relative to outside temperature and sunlight, often requiring working out the details and good switching points in between. Peer-to-peer information played a role in the market formation of such systems, as the first vendors to sell a 'technology independent assessment and renewable solutions' emerged in 2012 in Finland, over a decade after hybrid solutions started to become common. Hybrid S-RET systems also began to emerge stepwise in a pathway towards increasingly sustainable heating forms (Juntunen, 2014b).

To summarise this section, Internet forums have been important catalysts for learning how to use, adapt and innovate on heat-pumps in a cold climate context. The user activities have contributed through direct and indirect routes to the improvement of the vendor models targeted at this market. Innofusion characterises well these cycles where important further innovation happens during the "use phase", yet in connection to producer offerings.

4.5. Acceleration phase user intermediation

4.5.1. Fostering an appreciatively critical discourse of technology

The previous sections have characterised the activities and functions that user-run Internet forums play in transitions. They have several important features that deserve closer examination. The first issue is that these acceleration-phase Internet peer discussions pursue relatively little critical, alternative or pro-environmental technology discourse. Discussions revolve around and espouse the most seemingly neutral grounds of economic gain and technological optimisation or improvement. When we further interviewed active forum discussants, those with explicit environmental motivations regarded that displaying them in the forums would merely lead to unhelpful debate. This runs in contrast to many community energy settings where the critical discourse on alternative technology has been found a key characteristic (Smith et al., 2016b). Indeed, although the Internet forum discussions are about clean tech and renewable energy, topics such as reduction of carbon emissions are almost non-existent among the 300 000 messages of the main heat pump forum. When such topics are mentioned, emissions are considered a problem on a higher level or part of political decision making. In cases where technology is concerned, the emissions discussion is focused on other domains and technologies, such as transportation and cars, instead of on housing and heating. Open climate change scepticism can even be recognised in some exchanges.

We may ask what is happening. On the one hand the rather technical discussions on Internet forums are a more widespread genre than those that go on in the renewable energy forums – similar forums exist for bicycles, loudspeakers, various software products and so on – and the implicit and occasionally enforced code of discussion in such settings does not involve issues that could be regarded as ideological or political. On the other hand, the appeal to technicalities and economics does important work in legitimising and normalising the novel technology and discussions about it. As many scholars of technology have remarked, a distinct characteristic of technology is its ability to mask political choices behind seemingly neutral, normal and unstoppable progress (MacKenzie and Wajcman, 1999). One could even argue that continuing to foster a widely critical alternative discourse on the technological options that are to be widely diffused is to strip them from the prime source of power they may have as *technologies* within the discursive and political space of modern industrial societies. The mainstreaming and scaling up also run contrary to criticality *among citizen groups*, not just between the citizens and mainstream-policy actors (Smith et al., 2016b). The Finnish case of heat pumps also indicates that such capping of critical discourse can be effective. Whereas heat pumps were disregarded by the experts as not unsuitable for the Finnish context throughout the 1980s and 1990s (Heiskanen et al., 2014; Louhija et al., 2017), by 2016 the aura of novelty had vanished. By then, heat pumps were viewed by the public and experts alike as the normal and rational choice for a heating system, and they were installed in the majority of Finnish detached houses. Throughout this time, the Internet forum discussions helped open and keep open the 'black box' of technology in a *critical enough* manner for it to become appropriated, adjusted and improved for the specific national context but *appreciatively enough* to protect the technology from wholesale dismissals to which they also actively responded to.

4.5.2. The local community versus distributed internet communities

Our opening case portrayed a local energy community initiative in Valkeakoski, where actors benefitted from the shared creation of knowledge about technology, in their shared local conditions, pooling purchases and installations (Martiskainen, 2014). Community energy has been more generally held to be locality bound and premised on the sharing of finance and produce: energy produced 'by' and 'for' local stakeholders (Walker and Devine-Wright, 2008; Hargreaves et al., 2013; Smith et al., 2016a). Even as particular projects vary in regard to just how open and participatory or local they eventually are, the community is often defined as a local unit, within which shared interests, ownership and financing structures, as well as shared decision

Table 1
Case examples of community energy: a local community energy project and dispersed-structure community.

	A locality-centred community energy project	A dispersed-energy community created through knowledge sharing
Scale of the production unit	Decentralised small or medium scale	Decentralised small scale
Ownership of the production unit	Community owned	Owned by households
Daily operation	By an active group inside the community (or outsourced)	By the user, user responsibility
Knowledge sharing and community learning	Social learning when working together locally for a common goal	Individual operational work supported by an online community; characterised by common interest
The scale of the community knowledge pool	The participants in locally owned and run community energy projects and their networks	Thousands of users with similar equipment and a broad range of competences
Governance characteristics	Organised; requires governance structure, community control	Household control and autonomy, peer moderation of online community
Distribution: Sharing energy production	Microgrid or grid-connected; primarily for a group	Primarily for personal use; mostly grid-connected
The nature of discourse about niche technologies	Critical discourse around alternative technologies	Bounded critical and appreciative discourse around a niche technology
Functions in energy transition	Keeping up critical niches; helping to scale-up niche technology	Helping to scale up and mainstream niche technology

making rules, are possible. Often the maintenance and further development of the S-RET remain with the community as well, contributing to the upkeep and deepening of energy competences among the community members.

The Internet forums suggest that once the S-RET reach the acceleration phase, the locality bound community energy is no longer the only important community form and in fact, some of its characteristics may become superseded by ones that may be more effective in fostering widespread diffusion. The Internet forums portray a digitally mediated community form in which geographically dispersed users share an interest in the same class of technology and in a digitally mediated infrastructure, without committing to shared finance or produce (Hyysalo et al., 2016). The citizen users are connected to peers who run similar technologies and thus face similar questions in acquainting themselves with technological options, scaling the system(s), choosing from among the available brands, combining different S-RET forms, implementing, adapting and improving their systems. The digital communities may also feature subset communities that are interested and active in innovating new features to the technologies they have. The locality independent reach allows Internet communities to achieve much wider networks and higher coordination effects across the user base (Grabher and Ibert, 2014; Von Hippel, 2016), helping them to add momentum to accelerating the sociotechnical pathway (Heiskanen et al., 2011; Karnøe and Garud, 2012).

As to the factors that may drive users towards community energy or S-RET deployment by households, the differences are not decisive. Both provide returns of investment for owners, give local control and power to make energy generation decisions. However, some factors do favor household specific installations. Planning permissions are typically easier the smaller the production scale is. In heat production, smaller distance between generation and use results in lesser losses in energy transmission. Organisational and contractual complexity around individual installations is smaller than in medium scale community energy, which means greater agility in the set-up process. The peer support and expertise available in Internet communities has begun to compensate for the benefits community energy previously held over individual installations. It is thus foreseeable that increasing virtual connectivity among citizen users will create new dispersed community forms both in S-RET production and in linking producing users with those having storage or load (Juntunen and Hyysalo, 2015). Table 1 compares the key differences between local community energy and dispersed knowledge-sharing communities.

4.5.3. Internet forums within the ecology of user-side intermediaries for heat pumps

As we saw in the opening Valkeakoski case (4.1), there were multiple other actors that mediated heat pumps and their emerging market, forming what Stewart and Hyysalo (2008) characterise as an 'ecology of intermediation'. From the user perspective, however, these potential intermediary actors remained uninterested in many aspects of the heat pumps that were important for citizen users (research and academic institutions in particular), provided partial and self-interested assessment (resellers and installers in particular) or were difficult to reach and potentially offered too generic information for actual purchase decisions (actors such as local energy advisors and a national energy efficiency institution). Some intermediaries such as technical press and mass media did provide basic information, price comparisons, and tests but only rather sporadically for a continuously evolving market and without evaluations of realised performance or delivery by different vendors. In Appendix A we detail what different actors in this ecology of intermediation mediate and what they do not mediate to citizens. The overarching finding is that each intermediary actor takes on activities that are sensible for themselves and thus mediates for instance academic or within-industry knowledge only, not what would be functionally optimal for the emerging niche or citizen users. The result is that the market institutions and intermediary actors are not likely to coalesce in an optimum ecology regarding how citizen users could make informed acquisitions of novel technologies in the early phases of proliferation.

5. Discussion and conclusions

The user perspective on energy transitions is vital for better understanding their currently ongoing acceleration phases. As Schot et al. (2016) point out, transition nears completion when it has become more natural and routinised for users, as consumers and citizens, to make the choice in the new regime than in the old. However, to date transition studies have concentrated on the early exploration phase of transitions, or very broad historical analyses of past transitions, which has led to a tendency towards assuming that once the niche technologies mature they will then proliferate to society in ever widening numbers (Geels and Schot, 2007; Schot et al., 2016; Kanger and Schot, 2016), much akin to what diffusion of innovation model suggests (Rogers, 2010).

We have argued, answering our first research question, that this may be a too simplified view that obscures important transition dynamics. The changing of the early slow proliferation pattern into more rapid and widespread diffusion requires not only the adoption of S-RET but also the adaptation to, adjustment, intermediation and advocacy of S-RET on behalf of users. Examining heat pump proliferation to about 50% of maximal market penetration in Finland shows how reaching this point was not a matter of the mere diffusion. The heat pumps proliferated against the grain of the regime and in still partly underdeveloped niches (Heiskanen et al., 2017; Lauttamäki, 2018), shrouded by uncertainties as to their yield, savings, pay-back times, and scaling, as well as vendor and installer trustworthiness. The early proliferation remained very slow during the first two decades (1980–2006), only 60

000 installations emerged, but as technology and market conditions finally developed it picked up rapidly and the next decade (2007–2016) featured over tenfold growth (700 000). We stress that this growth period was not an automaton as it may look from just examining the numbers or a simple result of industry association becoming formed (Berninger et al., 2017): it was paired with and made possible by gradually developing market, knowledge institutions and technology characteristics. For instance, a purchase comparison that took nine months of part-time work to do in 2007 can be handled in mere hours of Internet forum search in 2016. What happened was a protracted **innofusion** pattern, the development of the sociotechnical characteristics of the technology during its diffusion (Fleck, 1993; Heiskanen et al., 2014; Hyysalo and Usenyuk, 2015), that laid preconditions for and overlapped with **diffusion**, the straight adoption of the technology (Rogers, 2010; Mignon and Bergek, 2016). At the heart of this development is that the alternative niche technologies do not spread in vacuum, but face different environmental, market, institutional and cultural conditions in new country settings.[7]

As part of the innofusion pattern, and answering our second research question, citizen users play important roles that enrich the understanding which transitions literature has held thus far. We show that user innovation may continue beyond the start-up phase (Hyysalo et al., 2013a, 2013b, 2016), unlike assumed by Schot et al. (2016) and Kanger and Schot (2016), following the reasoning in Von Hippel (2005). Similarly, we stress that *peer communities,* both local and internet based, are important in providing assistance among users who make consumption choices (Heiskanen et al., 2014; Smith et al., 2016b). These *user intermediary activities* serve several important functions in a transition. On the one hand, they provide qualifying market information, act as a back channel for complaints and improvement needs as well as provide evidence of value against counter claims from outside the niche. On the other hand, they aid re-contextualising the standard technology to national specifics through learning about a new technology and its use, contributing to demand articulation and technical improvement, and fostering appreciatively critical discourse of the technology. These areas are important in expanding the markets for S-RET beyond enthusiasts, environmentalists and other early adopters to reach the early majority of adopters that expects more exposure, clearer information and less uncertainty about new technology options in making their consumption choices. Indeed, what we see in the decade-long history of heat pump Internet forums is the enrolment of not only an increasing amount of new S-RET users but also new kinds of S-RET users and the technology getting pushed further towards the point where it becomes 'more natural' for the next potential consumer groups to make their heating system choice in the emerging new regime than in the old (Schot et al., 2016).

Importantly – and answering our third research question on how Internet forums act as user-side transition intermediaries – S-RET Internet forums enable and facilitate intermediary activities, which other actors, other intermediaries and locality based peer-to-peer exchanges do not, or even cannot, provide (Grabher and Ibert, 2014). Through Internet communities, citizen users get easy and quick access to technology and market information and they gain a polycentric knowledge repository which helps balance the various self-interested assessments around new technology. For those who become deeply interested, the Internet forums provide access to a highly competent peer community, to which one's specific problems and considerations can be presented. These characteristics allow citizen users to address the subject of household heating more effectively. The benefits include issues related to heat pump acquisition, such as the scaling of one's heating needs, choosing from among technological options and product alternatives, and comparing different vendor offerings. They also provide a platform to share a heating systems' ongoing operation, such as monitoring technology's real-life performance, troubleshooting and maintenance. For the more adventurous, Internet forums provide tips on modifying equipment. Lastly, they also act as voluntary watchmen by providing a channel in which to exercise customer voice regarding inadequate supplier performance and in which to contest claims by incumbent industry players or research institutes. In all these aspects, the locality-independent reach allows Internet communities to achieve wider networks and higher coordination effects across the user base than local communities could and in so doing they add momentum into the accelerating sociotechnical pathway (Heiskanen et al., 2011; Karnøe and Garud, 2012). These communities also allow higher variety in participant motivations and participation goals and require lesser member specialization than for instance open source software developmnet projects (von Krogh and von Hippel, 2003; Hyysalo et al., 2013b; cf. Grabher and Ibert, 2014). We therefore stress, that as important and as well-studied as the grassroots innovation movements and community energy initiatives are at the start-up phase (Hargreaves et al., 2013; Seyfang et al., 2014; Smith et al., 2016), the acceleration phase and its wide proliferation calls also for different aggregation and exposure capacities, which for instance internet communities can create.[8]

Regarding literatures on transition intermediaries (Kivimaa et al., under review) and innovation intermediaries (Howells, 2006; Stewart and Hyysalo, 2008) our enquiry underscores the contingencies regarding who are the actors within an emerging industrial field that take on specific user-side intermediary roles – the ecology of intermediation can in principle take many forms and remains subject to change as the field evolves. Within such an evolving ecology, citizen users can play an important part in reconfiguring dispersed knowledge resources to locally relevant assemblages, brokering connections between peers and suppliers, and facilitating learning about new technology and relevant actors, as well as about what is relevant information about the use and being a user of a new technology. Importantly, in the world of Internet-mediated connectivity, peers do not need to be physically *co-located* for many of these activities to become effective, unlike what was assumed by the early concepts on user-side innovation intermediaries, such as warm experts (Bakardjieva, 2005), local experts (Stewart, 2003) and tailors (Okamura et al., 1994). A future research avenue would be to investigate if other user-side intermediaries (beyond communities of citizen users) in the acceleration phase might benefit from increased digital presence and less environmentally conscious argumentation in diffusing new technology.

In terms of research designs, our study underscores that transitions framing is useful in the examination of how niche technology proliferates as this process is not just a matter of diffusion of a good but a wider process of coevolution between technology, market and user characteristics and thus a more systemic understanding of the interplay between niche and regime becomes useful. At the same time, this calls for new research designs within transitions research that dig in detail to actor processes, yet with explicit transition framing. As we saw in the present study, if one would have merely examined the proliferation

[7] Innofusion is likely to be more common with S-RET that are deployed in wide and variable ways, at different scales and with different ownership models (such as is the case with heat pumps, energy efficiency renovations or pellet and solid-wood burning) than in S-RET that require permitted and uniform installations, such as community-scale wind power (Juntunen and Hyysalo, 2015).

[8] Similar arguments have been made between locality based user innovator communities and Internet based open source communities (Baldwin and von Hippel, 2011; Von Hippel, 2016). Regarding energy transition, we can also observe some carry over between user intermediation from an already widely diffused niche technology to another, such as when peer advice in heat pump Internet forums proliferates into other, less-diffused renewables for the purpose of creating hybrid heating systems for a still higher eco-efficiency in a specific national context (Juntunen, 2014a, 2014b; Hyysalo et al., 2013b, 2016). These domestication and diffusion pathways are a research area that merits further attention. We can also conjecture that digital communities truly prosper if critical mass of discussants can be found and are thus not likely to be as effective as the predominant form of community as local communities are in the early explorative stages of development of alternative new technologies.

curve of the Finnish heat-pumps – a rather typical data granularity for a transitions study interested in niche-regime interplay (cf. Geels et al., 2016) – one could have come to falsely use Finnish heat pumps as evidence for rapid diffusion at acceleration phase and remain oblivious of the complex processes that underpinned the early stages of this proliferation.

To conclude, at the beginning of the study period, in the *early acceleration phase* in the specific market, heat pumps were shrouded with uncertainties and conflicting appraisals by experts and by media, as well as by peers. The citizen users needed to either make an uncertain purchase choice or invest considerable effort in finding out about the exact characteristics of new products. Such consumers were predominantly technologically or ideologically motivated ones. At the end of our study period, we are in the *late acceleration period*, during which heat pumps are normal goods whose benefits and drawbacks are relatively well articulated and readily available to routine, lazy and even disinterested users – the majority of whom would have been unlikely to adopt the novelty a decade earlier. Studying how routine and easy it is for the citizen user to make his or her consumption choice offers a proxy for how far the transition has progressed with respect to a particular technology and its cultural and market 'normality' in a particular national context. Peers play an important part in moving towards this market normality, and new Internet-based technologies and community forms allow them to have far-reaching effects on their fellow citizens. At the same time, there is always an ecology that coevolves consisting of local conditions, technology characteristics, suppliers, other intermediary actors and user practices. It is within this ecology that the peer Internet forums have been important catalysts for the diffusion of heat pumps in Finland, helping to move them beyond the early adopters and somewhat dubious payback, nascent market players and equipment stock riddled with varying hiccups in the cold climate.

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Appendix A. The ecology of Intermediaries in Finnish heat pump market in the period 2010–2014.

Intermediary in heat pumps	What mediates	To whom primarily mediates	How they mediate	What does not mediate to citizens	Extent
Citizens/peers					
Local communities, friends, neighbours (see above: Heiskanen et al. (2011, 2014, 2017)	Knowledge and information about technology and best practice, joint and coordinated purchases, experience from suppliers/installers	Peers	Personal/local contacts	Few things beyond the local area	Local
Internet forums (see above)	Providing qualifying information, influencing other actors in the market, providing empirical evidence, localizing knowledge, facilitating user-driven technical improvements, questioning regime actors	Peers, (resellers)	Via Internet discussion forums	The sharing of energy, work, resales	National
Public					
Local energy advisors Heiskanen et al. (2011)	What heap pump models exist, average yields, the fit to site specifics	Citizens, public agencies	Direct contact	Site-specific yield information per model, (de)recommending resellers or installers or hacks	Local
National Energy Efficiency Agency Motiva	What heap pump models exist, average yields, the fit to site specifics	Citizens, public agencies	Direct contact, Internet pages	Site-specific yield information per model, (de)recommending resellers or installers or hacks	National
Local authority building inspection	Installation guidelines, adequate installations for GSPS	Architects, builders, developers (citizens)	Guidelines, inspections	Site-specific yield information per model, (de)recommending resellers or installers or hacks	Local/ national
Research institutes Heljo and Laine (2005)	Technology tests, authoritative research results, expertize for evaluations	Primarily for industry and academia but also summaries are provided for the public	Commissioned research mainly for industry and research projects with public funding	Overall limited mediation in consumer segment	National

Private sector					
Industry association Heiskanen et al. (2011)	Information about technology and market development, professional training	General public, resellers, policy makers, authorities	Trainings, Internet pages	Business-sensitive information related to members	National
Resellers (see above: Heiskanen et al. (2014), Heiskanen et al. (2011)	Import and resale of technology, generic information (e.g. on specifications), installer and financing contacts, installation permission forms	General public, manufacturers	Direct interaction with customers and potential customers	Neutral information that is unbiased towards their sales items, business-sensitive information in general	National
Installers	Installation prices, installation options, installation work	Users, industry associations	Price quotas, direct contact, survey responses	Business-sensitive information (e.g. GSHP drilling depths per area), environmental harm from drilling	Local
Real estate agents (Rinkinen and Jalas, 2017)	Valuation and price information of installed heat pumps, the influence of technology on house valuation	Via online sales portals to the general public	Negotiating and setting up prices for real estate, providing information	Technology experience, incentivized to give biased information in order to support quick property sales	Local/ national
Insurance companies and incident reports	Insurance incident amounts per type and make	Authorities, resellers, vendors, building inspectors	Providing summarized numeric data, setting up norms	Overall limited mediation in consumer segment	National
Media					
Technical press and magazines	Basic information, price comparisons, tests	A technically oriented public	Print and online media	(de)recommending resellers, site-specific information (except in rare cases), sales, energy etc.	National
Mass media	Information on installations and example cases	All	Print and online media	(de)recommending resellers, sales only through adverts	Local/ national
Professional press	Basic information, price comparisons, tests	Building professionals	Print and online media	Reaches consumers only via third parties	National

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